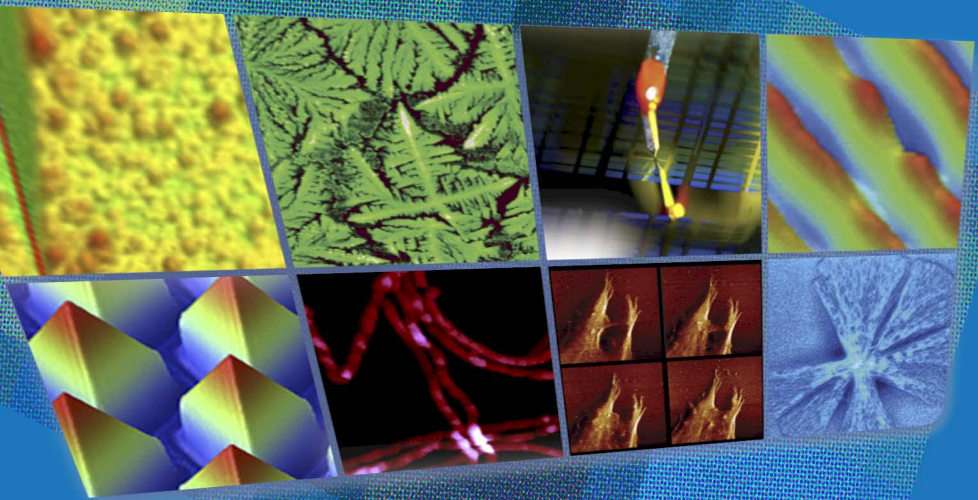
AFM Probes



Bruker AFM Advanced Training Class

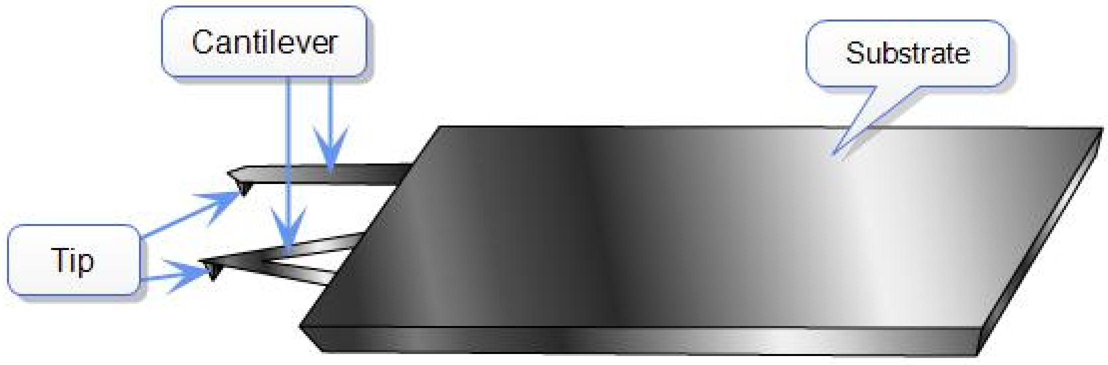
Atomic Force Microscopy
3D Optical Microscopy
Tribology
Automated AFM
Stylus Profilometry
Mechanical Testing,
Nano Indentation

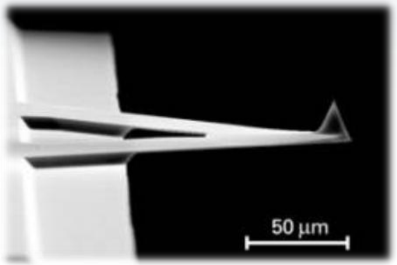
Innovation with Integrity

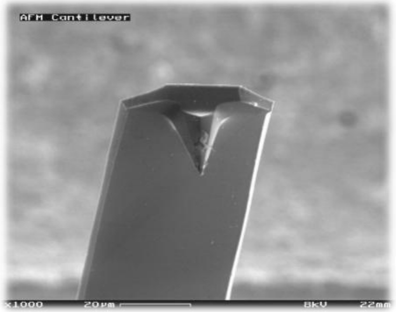
Bruker Nano Surfaces Division

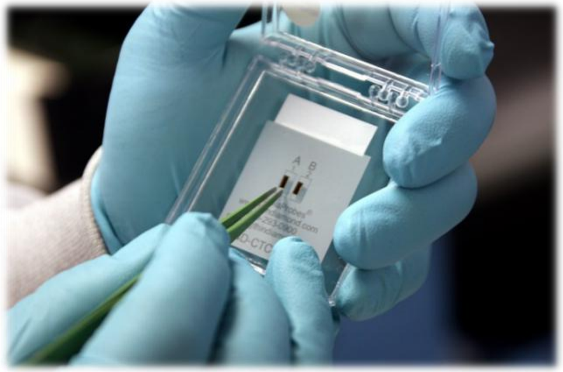
Common Rules of Probe Selection

AFM Probes





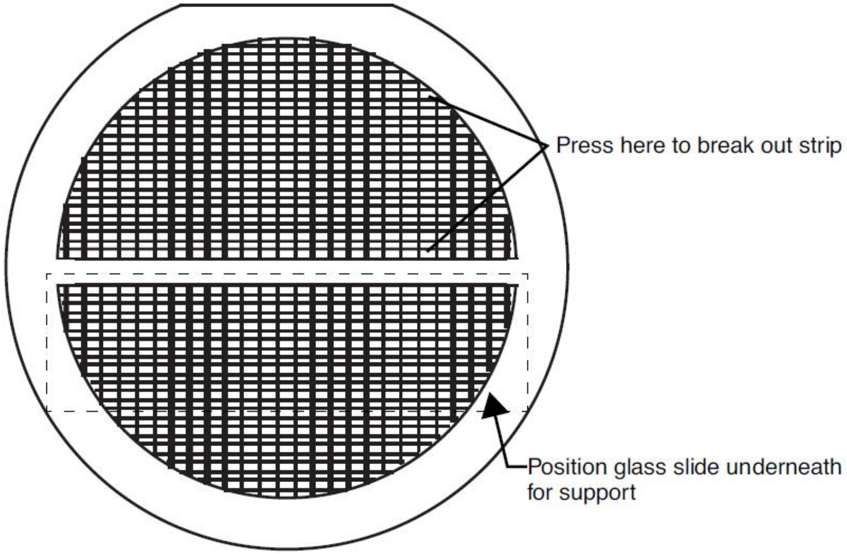




AFM probe:

- Components: Substrate, cantilever and tip
- Shapes: Rectangular, triangular
- Key parameters: Resonance frequency (f_0), Spring constant (k), Tip radius (r).

AFM Probes Package



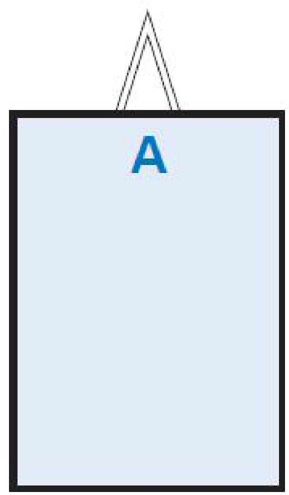
Wafer

10-Pack

AFM Probes Box

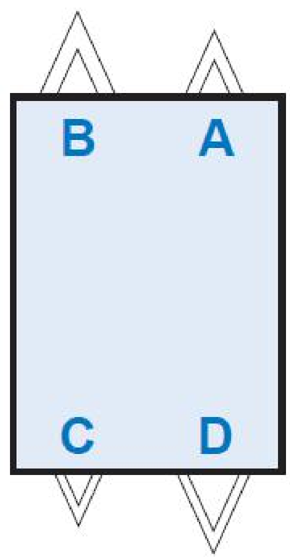
One Cantilever

- A on top
- Products:
  ScanAsyst-Air,
  ScanAsyst-Fluid,
  ScanAsyst-Fluid+



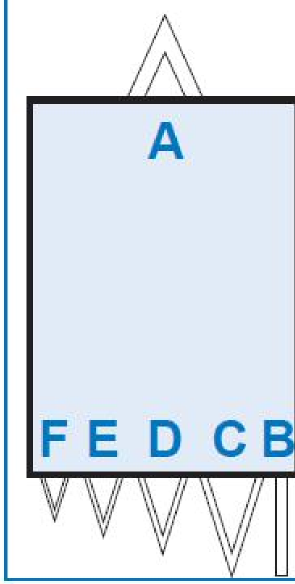
Four Cantilevers

- A & B on top
- C & D on bottom
- Products:
  SNL, DNP, DNP-S, NP,
  NP-S, NP-O, NPG, NP-UC

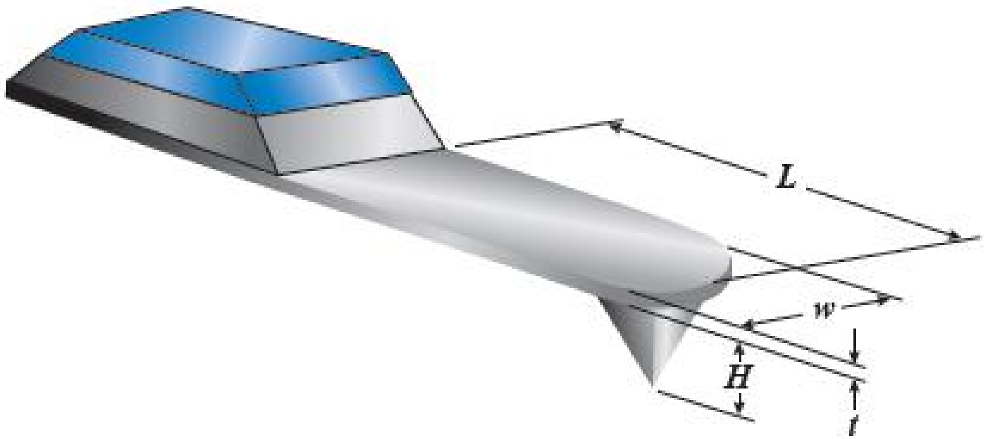


Six Cantilevers

- A on top
- B, C, D, E, F on bottom
- Products:
  MSNL, MLCT, MSCT,
  MLCT-O, MLCT-UC,
  MSCT-UC



Probe Parameters Overview



w – width of cantilever

H – tip height

p – cantilever mass per unit-length

$\rho_{air} = 1.18 kg / m^3$

$\eta_{air} = 1.86\text{x}10^{-5}\ kg / m \cdot s$

t – thickness of cantilever

f_0 – resonance frequency of cantilever (in Hz)

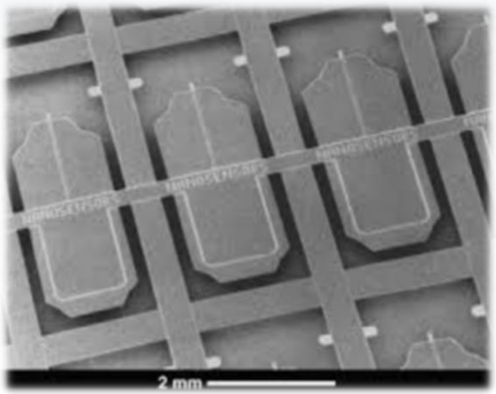
ρ – density of cantilever (silicon) = 2.33gm/cm^3 = 2330kg/m^3

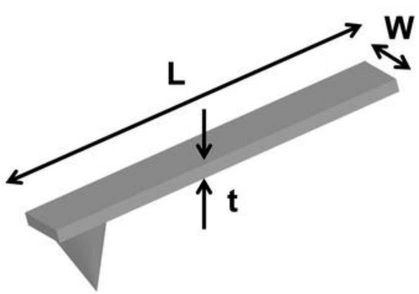
L – length of cantilever

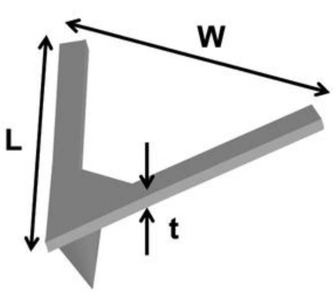
P – mass of tip

E – elastic modulus of cantilever = $1.39\text{x}10^{11} \text{N/m}^2$ (in the <110> direction)

Cantilever Parameters (1)







AFM probe materials:

- Silicon (Si)
- Silicon nitride (Si_xN_y)

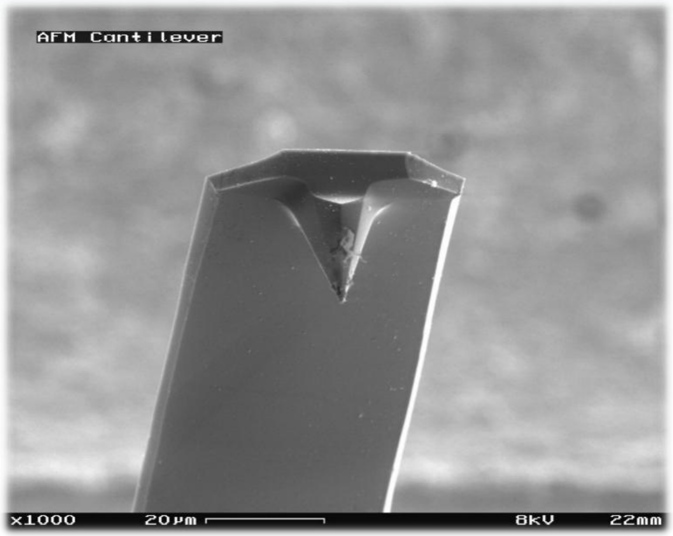
V-shaped cantilevers are less sensitive to lateral/torsional forces.

Probe Parameters	Probe material (Silicon)[35]	Probe Material (Silicon Nitride)[68]
r	> 1 nm	8-30 nm
t	1-7 µm	1-7 µm
W	0.4-40 µm	0.4-40 µm
L	90-100 µm	100-200 µm
k_N	0.05-9.9 N/m	0.006-15 N/m

Key parameters of AFM cantilever:

- Width (W)
- Length (L)
- Thickness (T)
- The dimension of the cantilever varies different probe designs and applications

Cantilever Parameters (2)



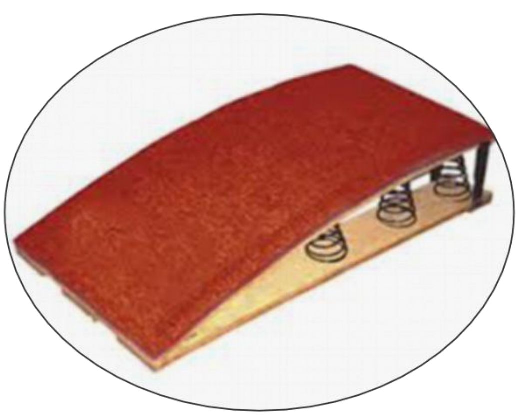
Spring Constant :

$$k = \frac{E}{4}\frac{w \cdot t^3}{L^3}$$

Resonance Frequency (without tip mass):

$$f_0 = 0.162 \cdot \sqrt{\frac{E}{\rho}} \cdot \frac{t}{L^2} \approx \frac{1}{2\pi}\sqrt{\frac{E}{\rho}} \cdot \frac{t}{L^2}$$

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$



Two very important parameters for AFM probe characterization:

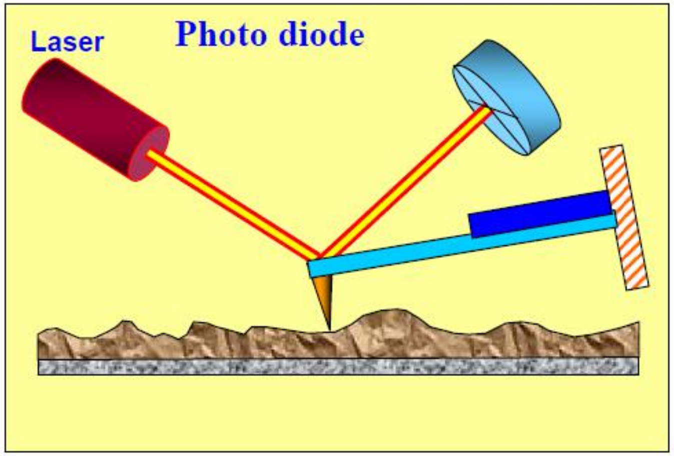
Spring constant (*k*)
Larger *k* indicates stiffer probe and stronger interaction between tip and sample.

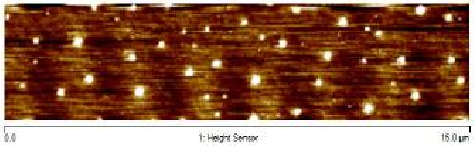
Resonance frequency (f_0)
AFM probe with larger *k* also has higher f_0

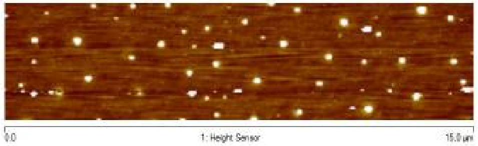
Cantilever Parameters (3)

- **Backside Coating**
- ✓ None coating: (R)TESP, (R)FESP, … **SUM: 1.5~2.5V**
- ✓ Al, Au, Pt/Ir, Co/Cr, …: OTESPA, SNL, SCM-PIT, MESP, … **SUM: 4.0~7.5V**

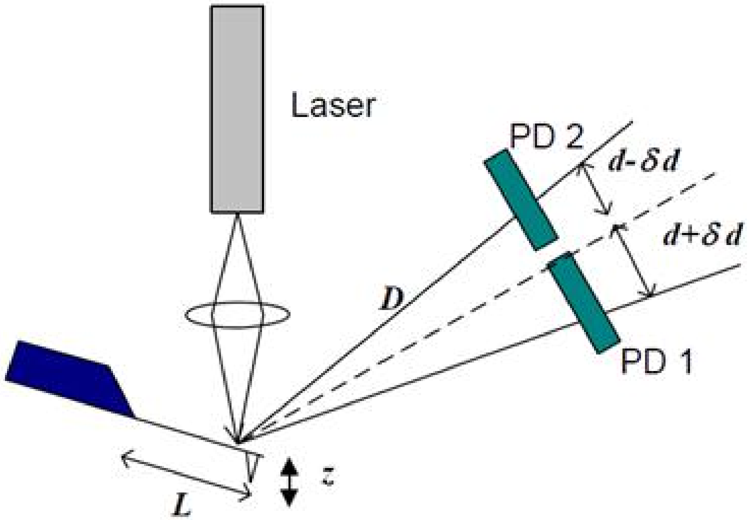
Some cantilever has a backside coating to increase its reflectivity. But this coating could be poor. In this case, usually **the SUM signal will be lower than normal**, and **image could have more noise and interference pattern because more light go to sample**.




With optical interference


Without optical interference

Cantilever Parameters (4)



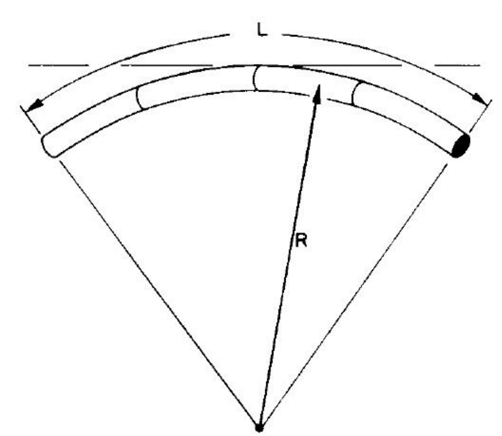
$$\delta d = 3\frac{D}{L}z$$

$$k = \frac{E}{4}\frac{w \cdot t^3}{L^3}$$

- Angular movement of the cantilever causes deflection change
- Deflection Sensitivity ∝ L; shorter cantilever for better deflection sensitivity (e.g. PFM application)

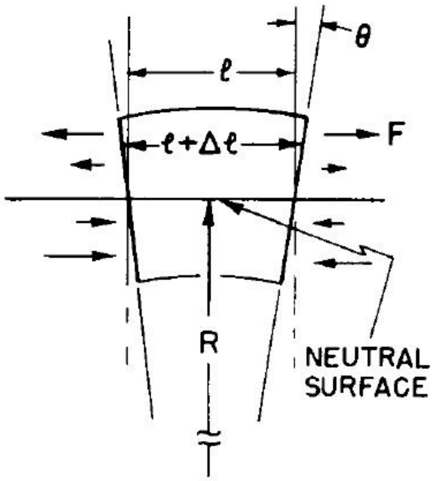
The Bent Beam

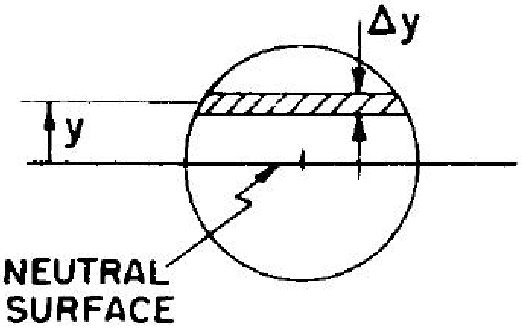
For pure bending, a thin transverse slice of the bar is distorted. The material below the neutral surface has a compressional strain which is proportional to the distance from the neutral surface. So the longitudinal stretch is proportional to the height y.



$$\frac{F}{A} = E\frac{y}{R}$$

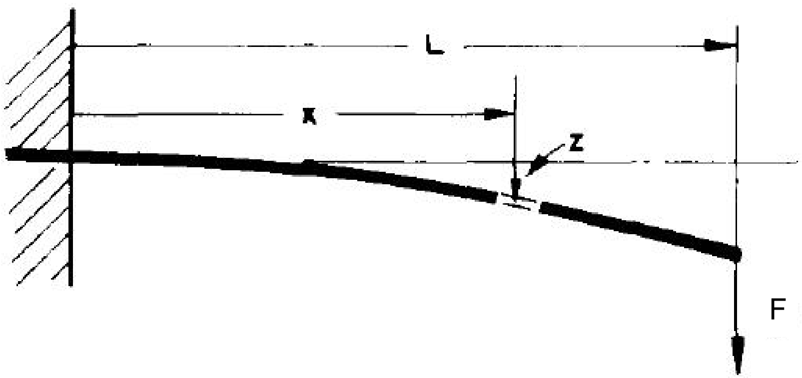
Bending moment:





The Deflection of a Cantilever

Let's call the deflection at distance x from the fixed end z, we want to know z(x). For small deflection, we assume the beam is long in comparison with its cross section. The curvature 1/R of any curve z(x) is

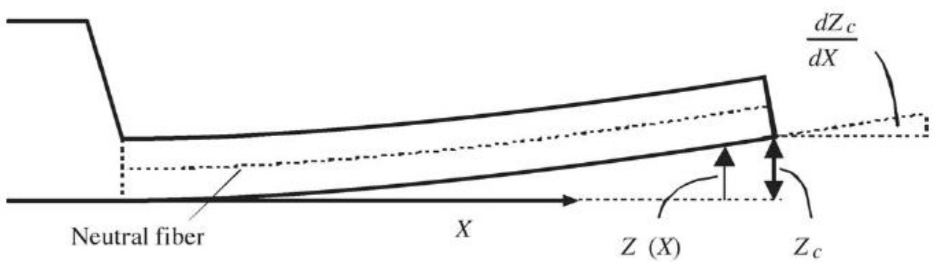


Since we are interested only in small slopes, above equation becomes:

Using our assumptions that z(0) = 0 and dz/dx = 0 at x =0

Relationship Between
PSPD Signal and Cantilever Deflection

The deflection of the cantilever is usually measured using the optical lever technique. When a force is applied to the probe, the cantilever bends and the reflected light-beam moves through an angle equal to twice the change of the endslope dZ_c/dX.



For a cantilever with a rectangular cross-section of width w, length L, and thickness t_c, the change of the endslope is given by

$$\frac{dZ_c}{dX} = \frac{6FL^2}{Ewt_c^{\ 3}}$$

Where E is the Young's modulus of the cantilever material. F is the force applied to the end of the cantilever in normal direction.

The deflection of the cantilever is given by

$$Z_c = \frac{4FL^3}{Ewt_c^{\ 3}} = \frac{2}{3} L \frac{dZ_c}{dX}$$

Hence, ***the deflection is proportional to the PSPD signal***. One should, however, keep in mind that these relations only hold under equilibrium condition.

Deflection Detection

When a force is applied to the tip, the cantilever bends and the reflected light-beam moves through an angle equal to twice the change of the endslope

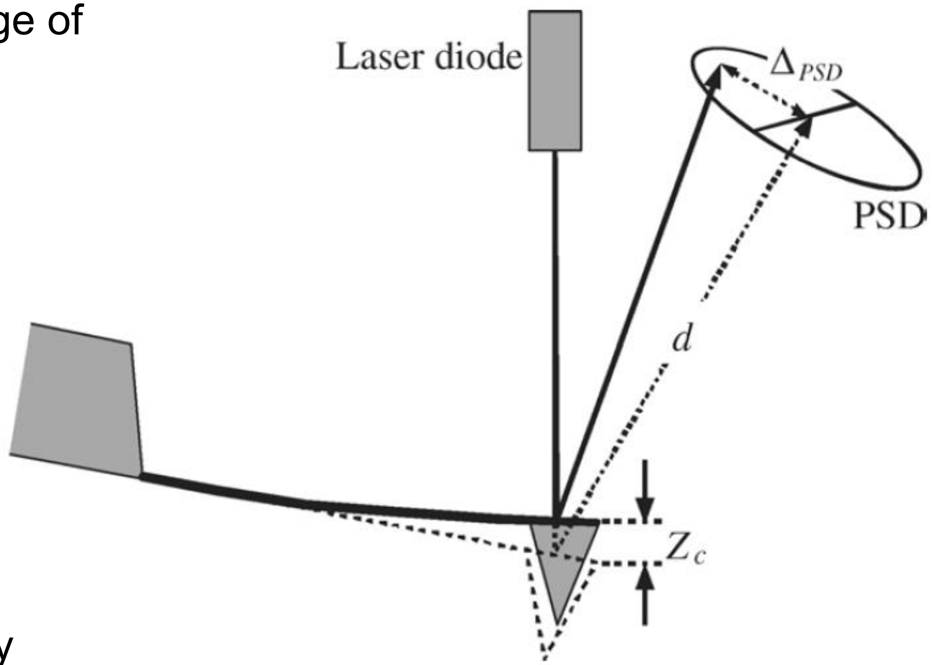
$$\alpha = \Delta(dZ_c/dX)$$

If the detector is a distance d away from the cantilever the laser spot moves on the detector through a distance

$$\Delta_{PSD} \approx 2d \tan\alpha = \frac{FL^2 d}{EI}$$

The deflection of the cantilever is given by

$$Z_c = \frac{FL^3}{3EI} = \frac{\Delta_{PSD} L}{3d}$$



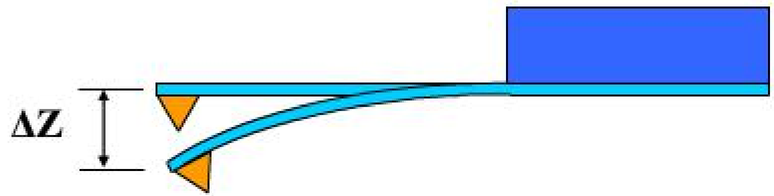
Cantilever Parameters (5)

- **Cantilever Tuning**
  - ✓ In Air: Q ~ 200-600
  - ✓ In Fluid: Q ~ 5-80

In tapping mode, the cantilever oscillates at certain frequency. When tune the cantilever, make sure to pick the cantilever's natural frequency. If **the cantilever tuning curve is not clean, has multiple tuning peaks, or has abnormal Q**, this will **directly affect the image quality**.

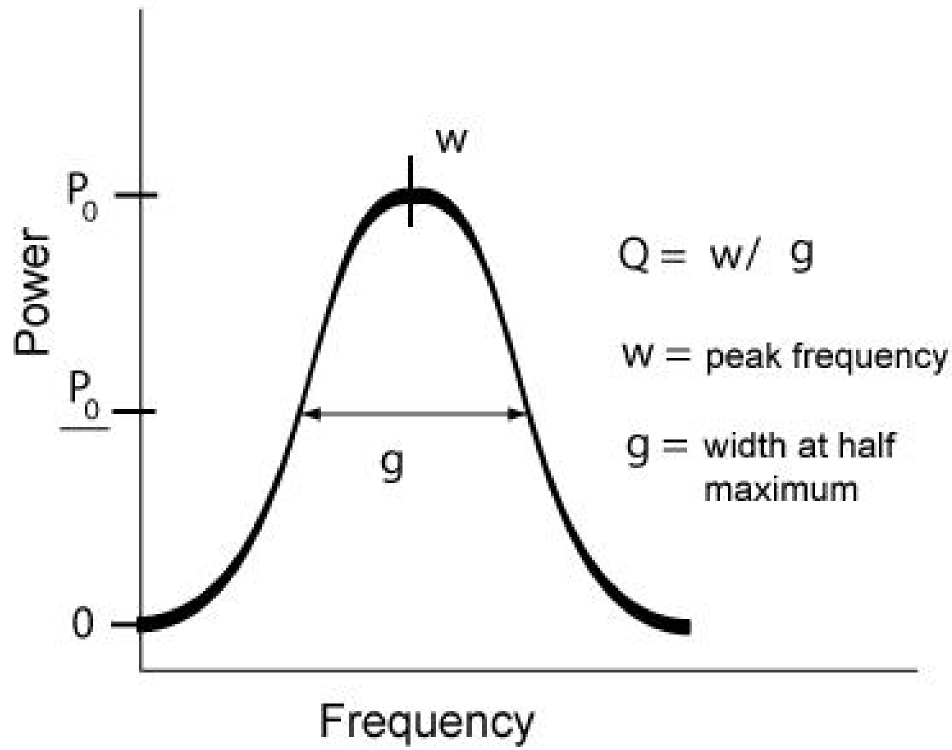
$$Q = \omega_0 m / \gamma$$

$$\omega_n = \frac{\lambda_i}{l^2}\sqrt{\frac{EJ}{\rho S}}$$



$\lambda_1 = 3{,}52$ $\lambda_2 = 22{,}04$

Cantilever Response Time

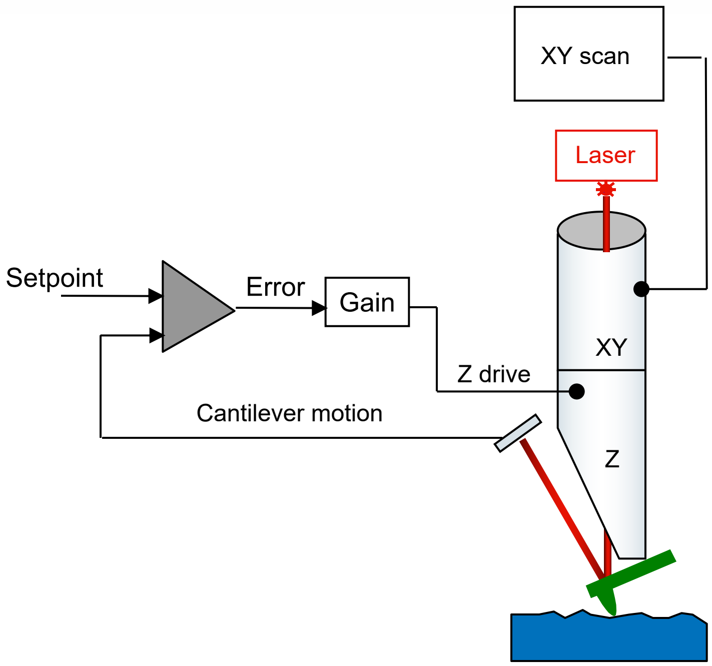


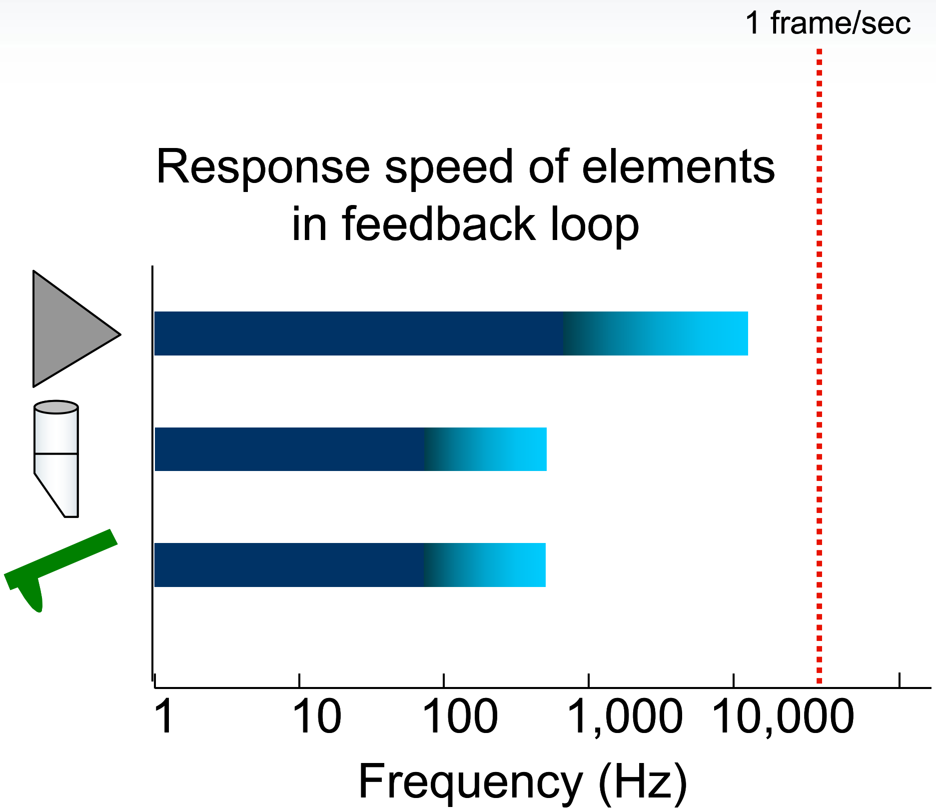
Higher Q indicates a lower rate of energy loss relative to the stored energy

$$BW \propto \frac{fr}{Q}$$

- Cantilever response time constant: $\tau = 2Q/f_0$

Go to Fast

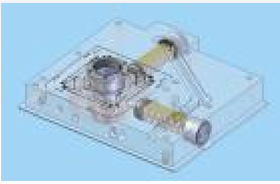




- The system is only as fast as its weakest link.
- Bandwidth (not tip velocity, or frame rate) is the fundamental metric.

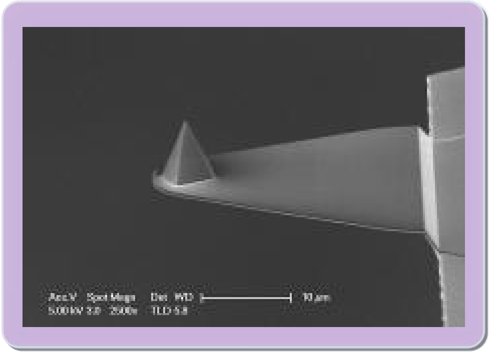
Fastscan Hardware

- X-Y Flexure Scanner, Removable Z-Scanner.



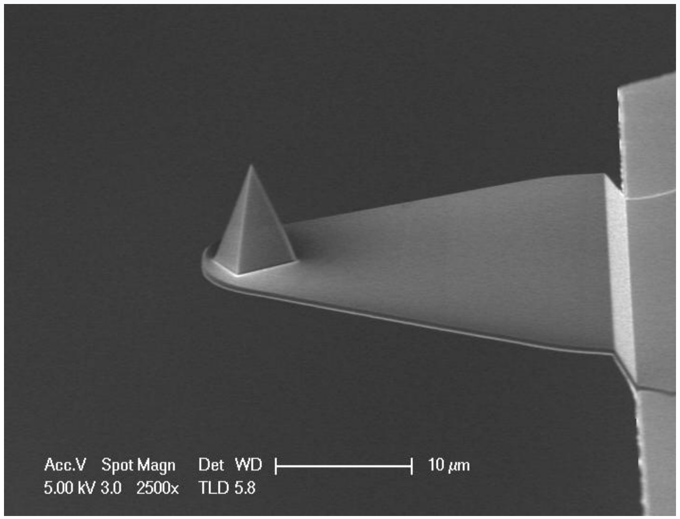
- Air and Fluid, one scanner and includes scanner wash station for decontamination.

- Broadband Probes.

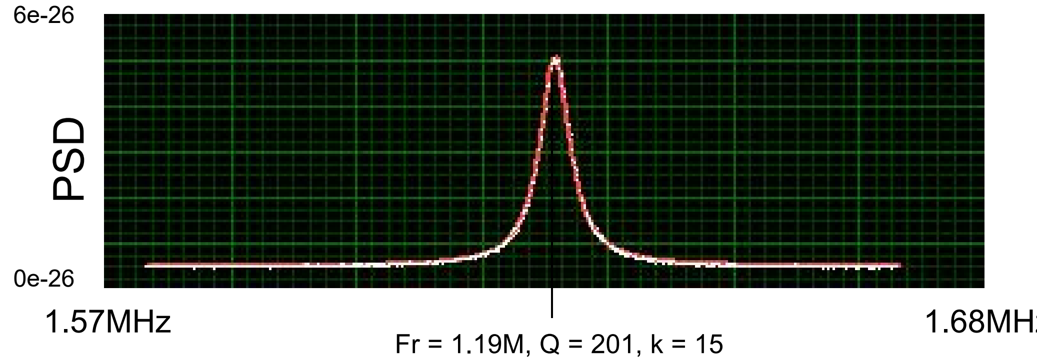


FastScan Probe Specifications			
Cantilever Specifications:	**Broadband-A**	**Broadband-B**	**Broadband-C**
Preferred Medium	Air	Fluid	Fluid
Shape	Triangular	Triangular	Triangular
Length - Nominal	27µm	30µm	40µm
Width	32µm	32µm	40µm
Frequency (MHz)	1.25 MHz	400 KHz	250 KHz
Spring Constant (N/m)	17 N/m	4 N/m	1.5 N/m
Material	Silicon Nitride	Silicon Nitride	Silicon Nitride
Thickness - Nominal	0.6µm	0.3µm	0.3µm
Thickness - Range	0.55-0.65µm	0.25-0.35µm	0.25-0.35µm
Backside Coating	100 +/- 10nm of Al	60 +/- 10nm of Ti/Au	60 +/- 10nm of Ti/Au
Tip Specifications:	**Broadband-A**	**Broadband-B**	**Broadband-C**
Geometry	Anisotropic	Anisotropic	Anisotropic
Tip Height	2.5-8µm	2.5-8µm	2.5-8µm
Front Angle	15 +/- 5°	15 +/- 5°	15 +/- 5°
Back Angle	25 +/- 5°	25 +/- 5°	25 +/- 5°
Side Angle	17.5°	17.5°	17.5°
Tip Radius	5nm	5nm	5nm
Tip Radius - Maximum	12nm	12nm	12nm
Tip Setback - Nominal	5µm	5µm	5µm
Tip Setback - Range	0-7µm	0-7µm	0-7µm

Fastscan Probe Design



Typical Probe and Lorenz Best Fit



$$F \propto \frac{k}{Q}$$

$$BW \propto \frac{fr}{Q}$$

- Probe Details

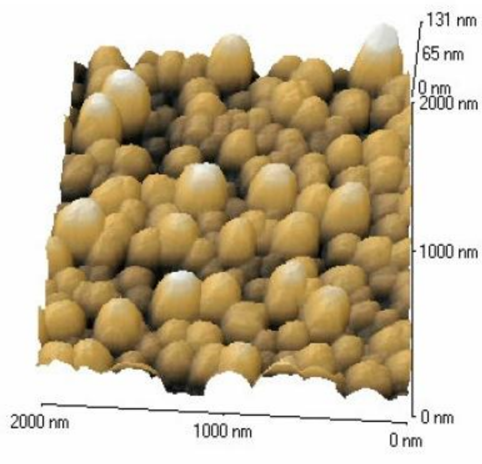
	L (um)	W (um)	fr (MHz)	k (N/m)	t (um)	Tip Height	ROC	TSB	Backside Coating
Style A	27	32	1.25	17	0.6	2.5 um to 8 um	5 nm	5 µm	Yes
Style B	30	32	0.40	4	0.3				
Style C	40	40	0.25	1.5	0.3				

Tip Parameters (1)

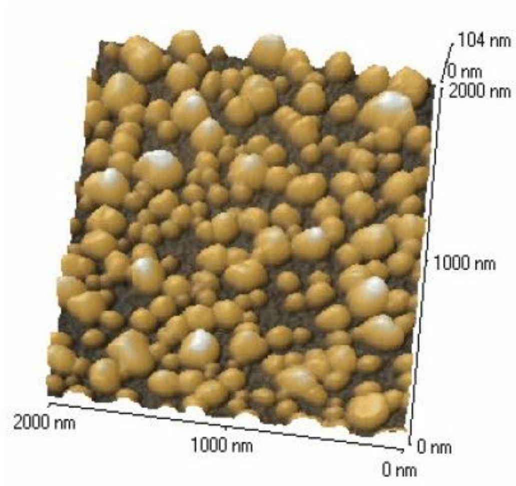
➢ **Tip Radius**

✓ **The radius of curvature of the end of the tip will determine the highest lateral resolution** obtainable with a specific tip. The sidewall angles of the tip will also determine its ability to probe high aspect ratio features.

3D Topographic Image of Gold Grains

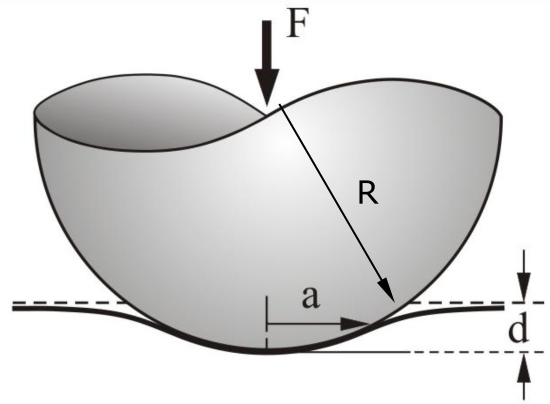


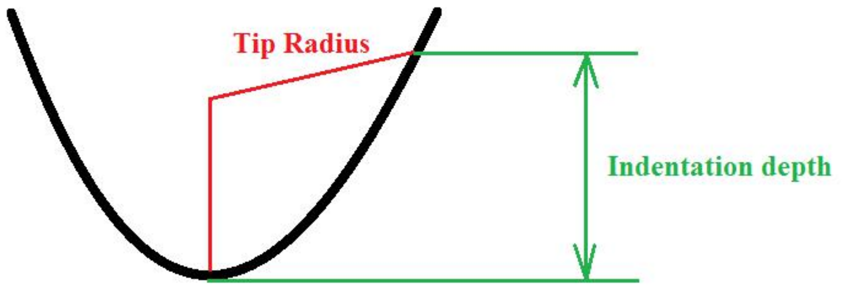
Normal Probe



Sharpened Probe

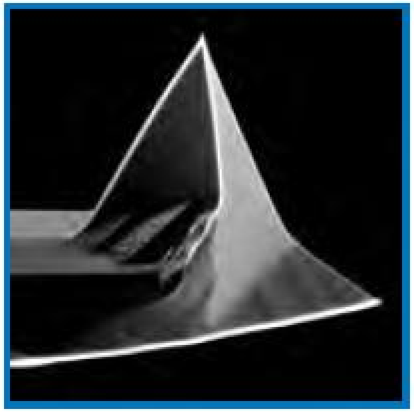
Tip Radius for DMT Model

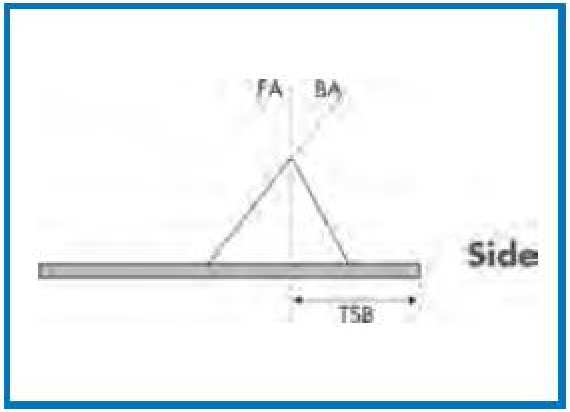


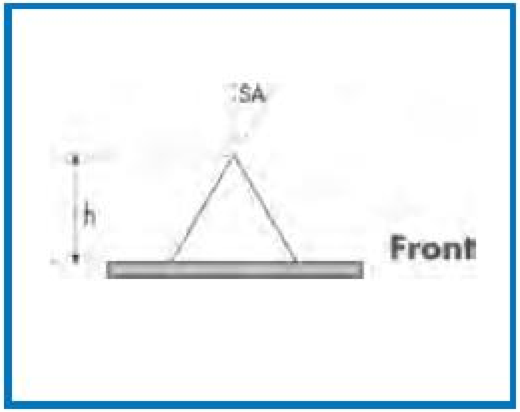


- For spherical probe, the tip radius is independent to the indentation depth
- For conical probe that tip end is not a part of a sphere, the effective tip radius depends on indentation depth
- Two information needed to calibrate tip radius:
  1. Tip shape
  2. Indentation depth

Tip Parameters (2)



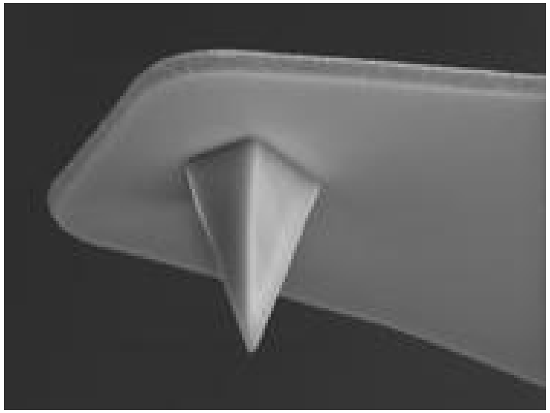




Tip	Tip Radius (nm)	Front Angle (°)	Back Angle (°)	Tip Set Back (μm)	Tip Height (μm)	Side Angle (°)
All	8	15	25	15	17.5	17.5

- FA: Front Angle
- BA: Back Angle
- TSB: Tip Set Back
- SA: Side Angle
- H: Tip Height

Tip Half Angle



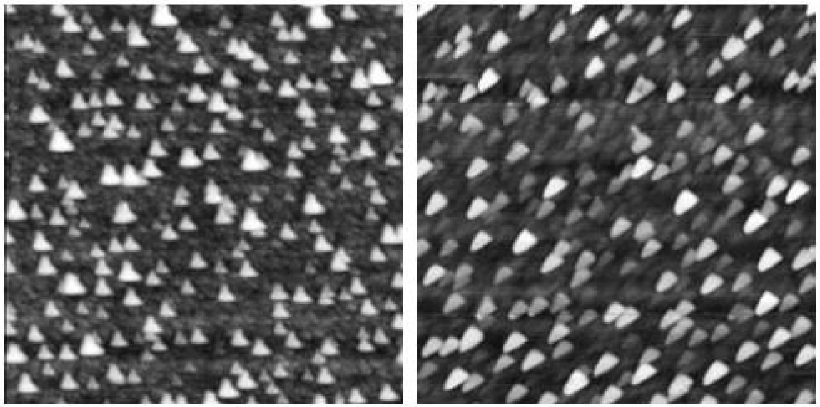
Tip Schematic

Geometry:	Rotated (Symmetric)
Tip Height (h):	2.5 - 8.0µm
Front Angle (FA):	15 ± 2.5º
Back Angle (BA):	25 ± 2.5º
Side Angle (SA):	17.5 ± 2.5º
Tip Radius (Nom):	20nm
Tip Radius (Max):	60nm

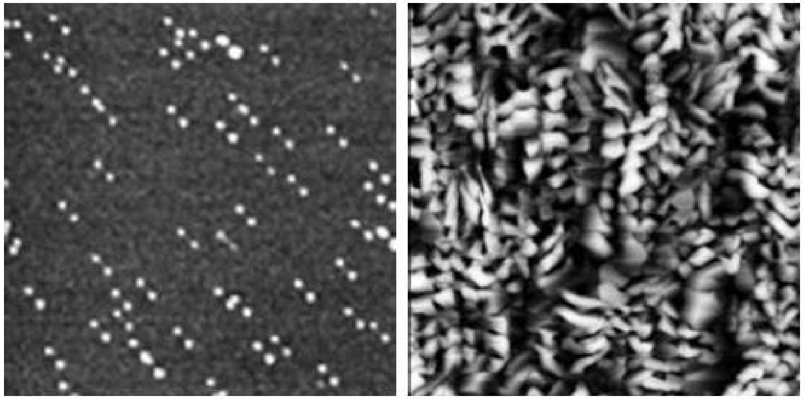
$$\text{Half angle} = \tan^{-1}\left(\sqrt{\tan\alpha * \tan\beta}\right)$$

$$\alpha = \frac{FA+BA}{2} \qquad \beta = \frac{SA_1+SA_2}{2}$$

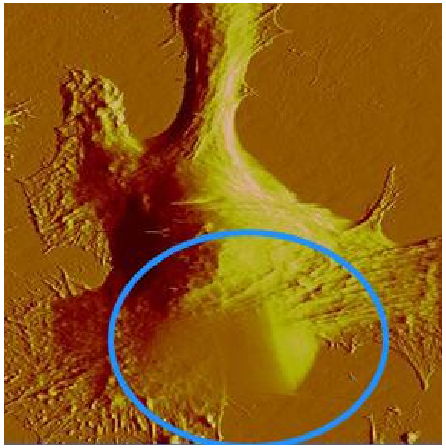
Typical Image Artifacts Caused by Tip



Dull or dirty tip



Double or multiple tips



Tip Angle

- AFM image is a convolution of sample topography and tip shape

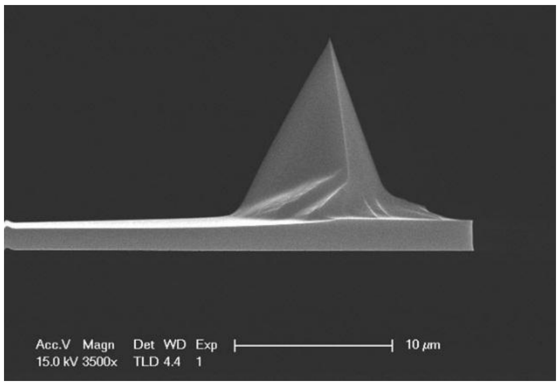
Tip Parameters (3)

- **Probe Tip Coating**
  - ✓ Electrical Measurement: Need conductive tip
  - ✓ Magnetic Measurement: Need magnetic tip

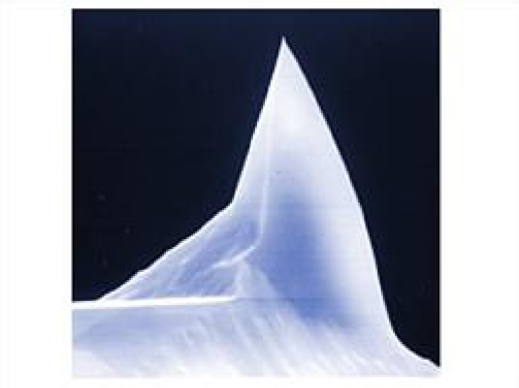
Coating damage may lead to no electrical/magnetic signal.

Tip Parameters (4)

- **Tip Geometry**



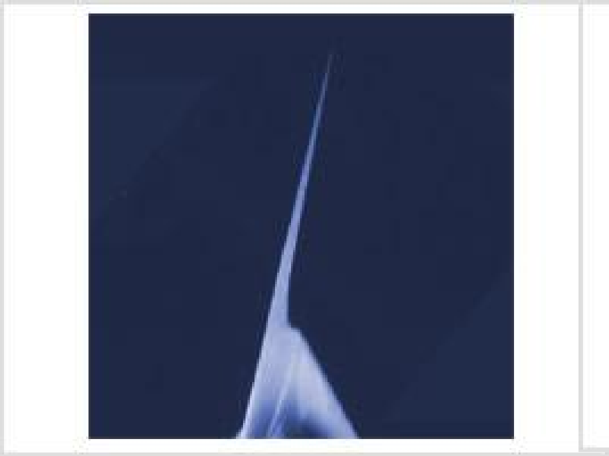
Rotated (Symmetric)



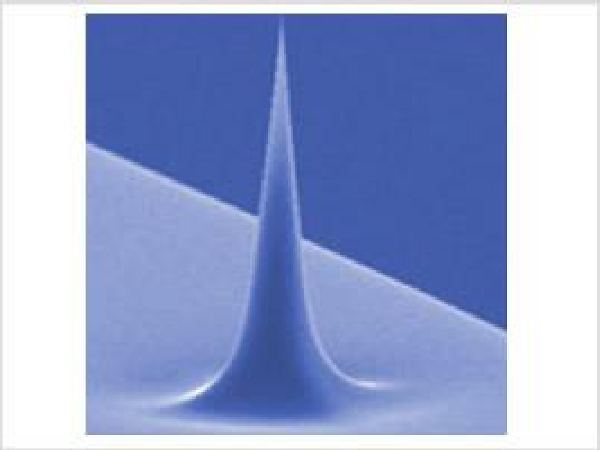
Standard (Steep)

Pyramid

Tipless



High Aspect Ratio

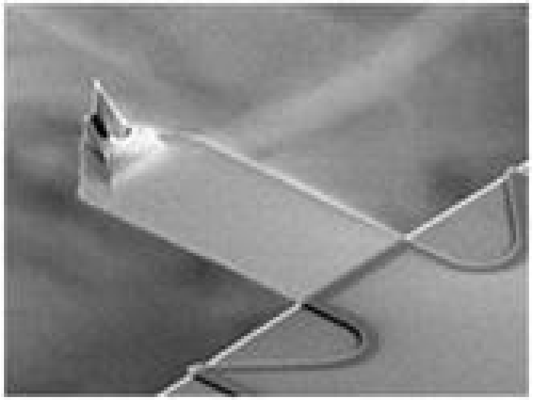


Conical

Tip Parameters (4)

- **Tip Geometry**

Super Sharp



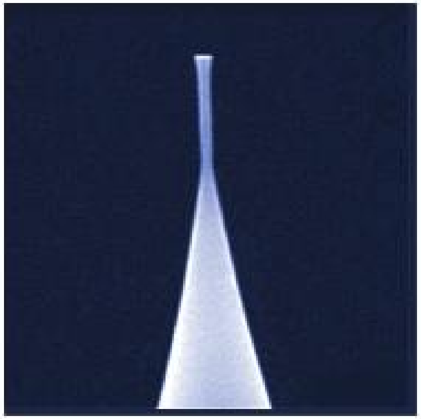
Visible Apex

Rotated (Symmetric): for symmetric imaging

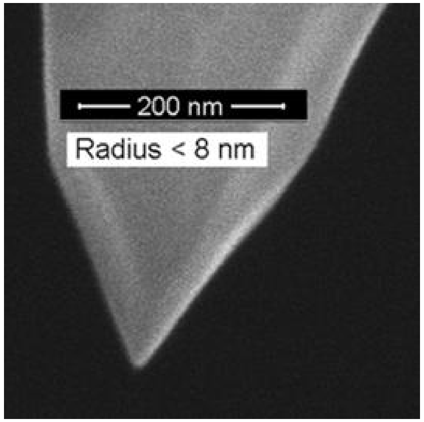
Tipless: for tip modification

Super Sharp/High Aspect Ration: for high resolution

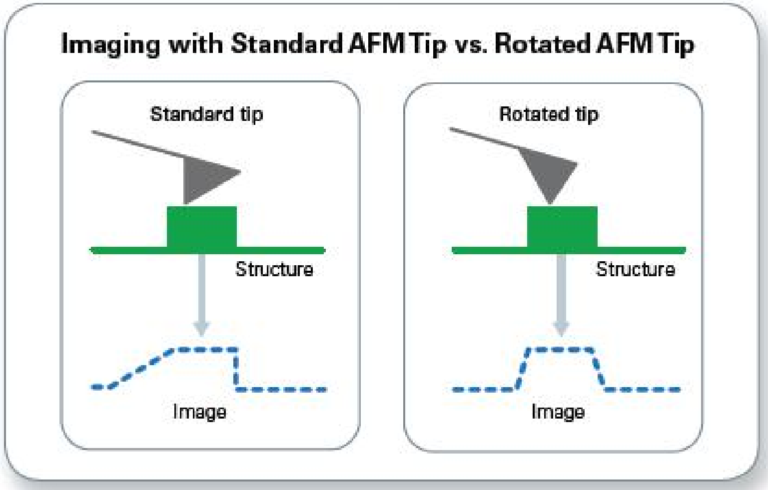
Visible Apex: for precise positioning



Critical Dimension

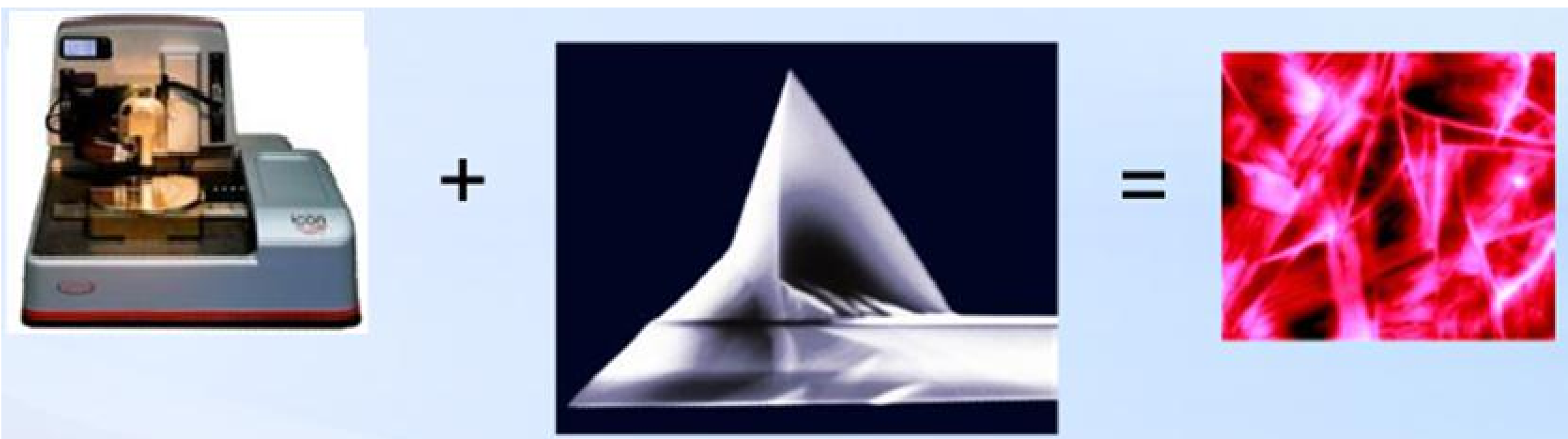


Solid Wire



Importance of Probe Selection

- Good Instrument + Good Probe = Good Image



Factors to Be Considered

1. Sample Properties to be Measured

Topography
Viscoelasticity
Electric Properties
Magnetic Properties

2. Environment

Air
Liquid

3. Imaging Mode

Contact Mode
Tapping Topography
Tapping Phase
TRmode

Common Rules For Probe Selection

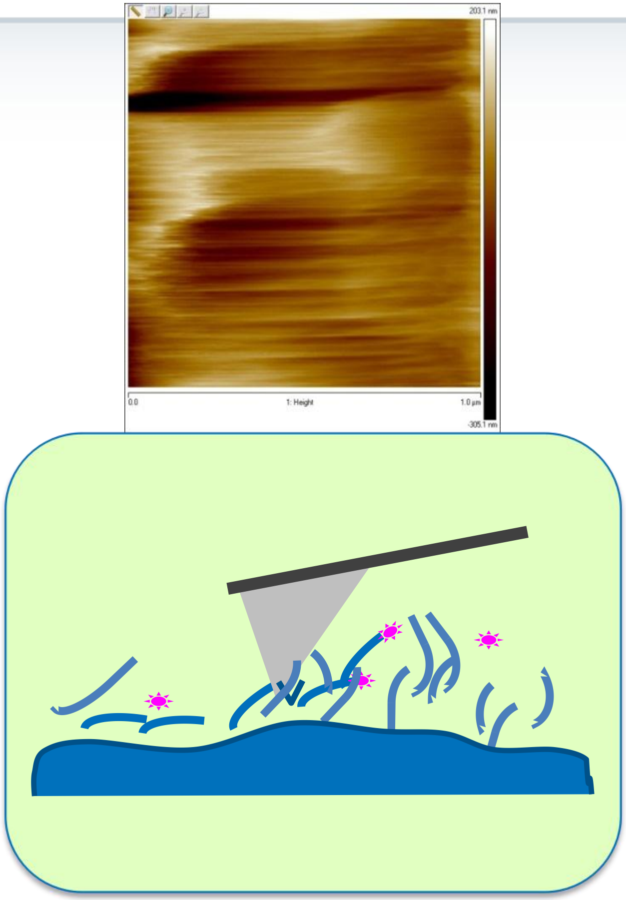
- ✓ Higher spring constant cantilever leads to larger interaction force between tip and sample when the deflection is constant: Softer samples prefer softer cantilevers
- ✓ Higher resonance frequency cantilever leads to faster response time (higher bandwidth): Fast scan applications prefers higher resonance cantilevers
- ✓ Lower deflection sensitivity leads to higher sensitivity to detect small deflection
- ✓ Lower spring constant cantilever leads to better force sensitivity to measure small force
- ✓ Backside coating improves cantilever reflection: High SNR applications prefers cantilever with backside coating
- ✓ Smaller tip radius leads to higher later resolution: High resolution imaging applications prefers small tip radius
- ✓ Both tip angle and tip radius can affect final topography images
- ✓ Front side coating is used for properties mapping
- ✓ Different tip geometry is used for different applications

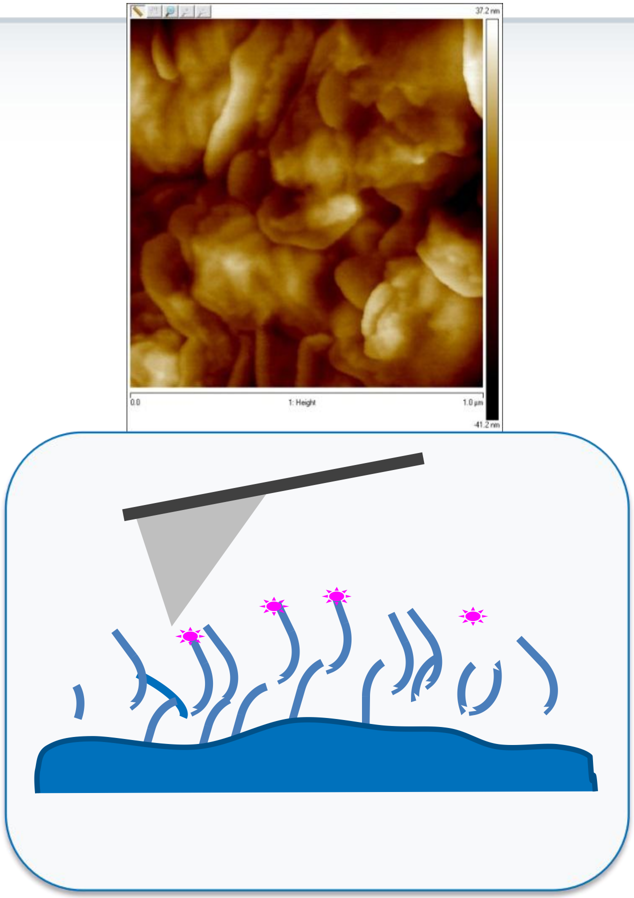
Probe Selection for Difference Applications

SPM Primary Imaging Modes

P = P(z)	Working Mode
Tunneling Current *i*	Scanning Tunneling Microscope (STM)
Cantilever Amplitude A	Tapping Mode AFM™
Cantilever Deflection D	Contact Mode AFM
Cantilever TR Amplitude A_t	Torsional Resonance Mode (TRmode) AFM™
PeakForce F	PeakForce Tapping AFM™

SPM Primary Imaging Modes





Sticky molecule

Contact mode

Tapping mode

PF-Tapping mode

Contact Mode Probes

Spring constant k is usually less than 5N/m.

- ✓ High resolution: SNL serials, MSNL serials(Silicon tip, Nitride cantilever)
- ✓ Common application: DNP serials, DNP-S serials, MLCT serials, NPG serials (Nitride tip, Nitride cantilever)

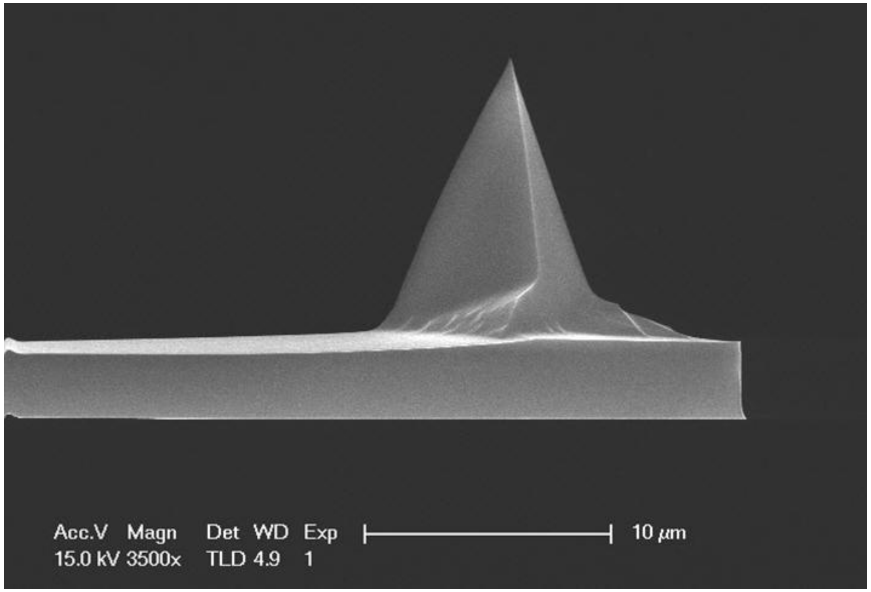
SNL-(10/W), DNP(/-10), DNP-S(/10), NPG(/-10)
4 levers 0.06-0.35N/m; Au Reflex Coating

MSNL-(10/W), MLCT (suitable for bio samples)
6 levers, 0.01-0.50N/m, Au Reflex Coating

Contact Mode Probes

Spring constant k is usually less than 5N/m.

✓ Common application: ESP serials (Silicon tip, Silicon cantilever)

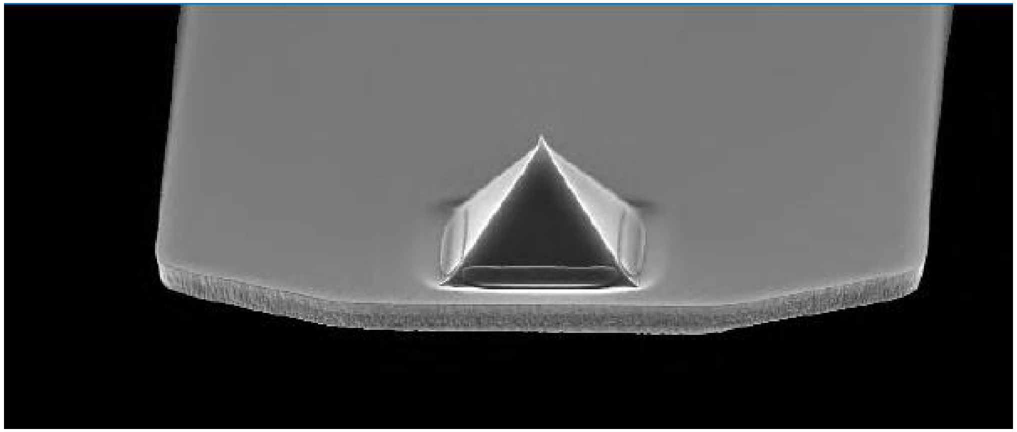


ESP serials:
RESP(/A/W/AW)-10, 0.1N/m
RESP(/A/W/AW)-20, 0.9N/m
RESP(/A/W/AW)-40, 5N/m
ESP(/A/W/AW)-V2, 0.2N/m

LFM Probes

Spring constant k is usually less than 5N/m and rectangle cantilever is recommended.

✓ LFM probes: ORC8, ESP serials



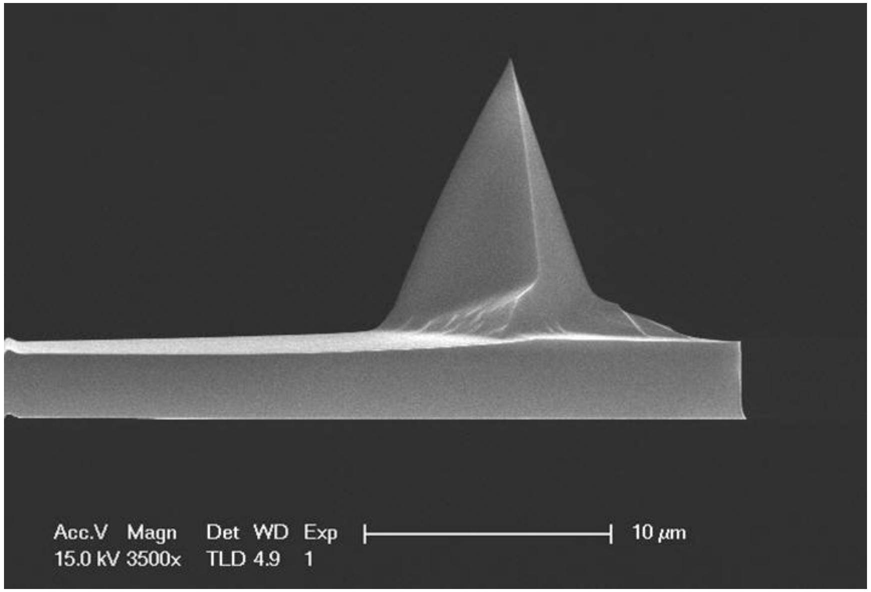
ESP serials:
RESP(/A/W/AW)-10, 0.1N/m
RESP(/A/W/AW)-20, 0.9N/m
RESP(/A/W/AW)-40, 5N/m
ESP(/A/W/AW)-V2, 0.2N/m

Name	Mount	Description	Pack Size
ORC8-10	Unmounted	Sharpened, 4 Rectangular Cantilevers 0.06-0.82N/m, Au Reflective Coating	10
ORC8-W	Unmounted	Sharpened, 4 Rectangular Cantilevers 0.06-0.82N/m, Au Reflective Coating	490

Tapping Mode Probes

Spring constant k is usually lager than 2N/m.

- ✓ Common application: TESP serials, FESP serials & LTESP serials
- ✓ Ultrahigh resolution: TESP-SS(/W)



TESP serials:
RTESP(/A/W/AW)-150, 6N/m
RTESP(/A/W/AW)-300, 40N/m
RTESP(/A/W/AW)-525, 200N/m
TESP(/A/W/AW)-V2, ~42N/m
OTESPA-R3, 42N/m

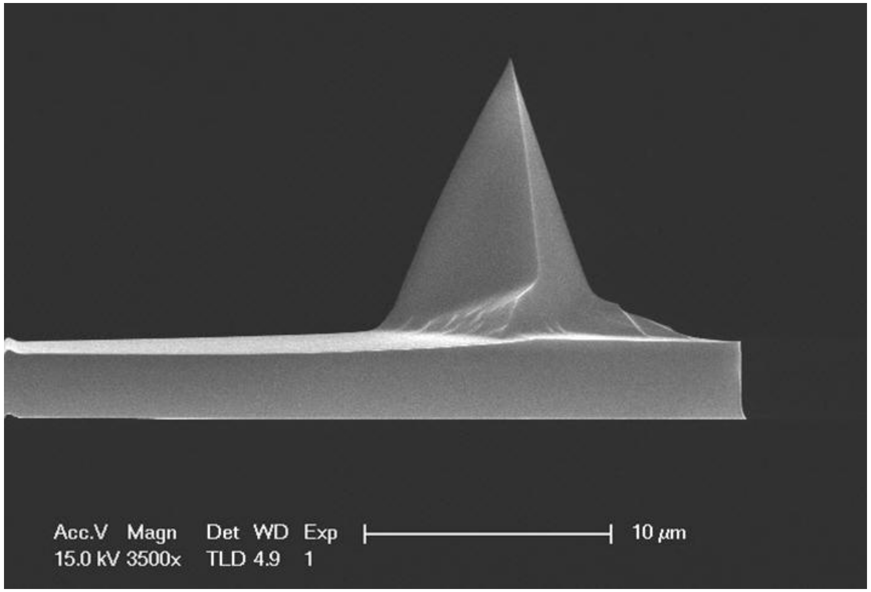
LTESP serials:
LTESP(/A/W/AW)-V2, 48N/m
OLTESPA-R3, 2N/m

FESP serials:
RFESP(/A/W/AW)-75, 3N/m
RFESP(/A/W/AW)-190, 35N/m
FESP(/A/W/AW)-V2, 2.8N/m

Phase Imaging Probes

Prefer cantilever with moderate spring constant, ~2-5N/m

✓ Phase imaging probes: TESP serials, FESP serials & LTESP serials



TESP serials:
RTESP(/A/W/AW)-150, 6N/m
RTESP(/A/W/AW)-300, 40N/m
RTESP(/A/W/AW)-525, 200N/m
TESP(/A/W/AW)-V2, ~42N/m
OTESPA-R3, 42N/m

LESP serials:
LTESP(/A/W/AW)-V2, 48N/m
OLTESPA-R3, 2N/m

FESP serials:
RFESP(/A/W/AW)-75, 3N/m
RFESP(/A/W/AW)-190, 35N/m
FESP(/A/W/AW)-V2, 2.8N/m

MPP Probes

$$\mathrm{MPP} - ABCDE - Z$$

MPP: Metrology Point Probe
A: The length of cantilever
- 1 – Short (Tapping line of probes)
- 2 – Middle (Multi line of probes)
- 3 – Long (Contact line of probes)

B: The thickness of cantilever
- 1 – Middle (Tap300, Multi75, Contact20)
- 2 – Thin (Tap150, Multi40, Contact10)
- 3 – Thick (Tap525, Multi190, Contact40)

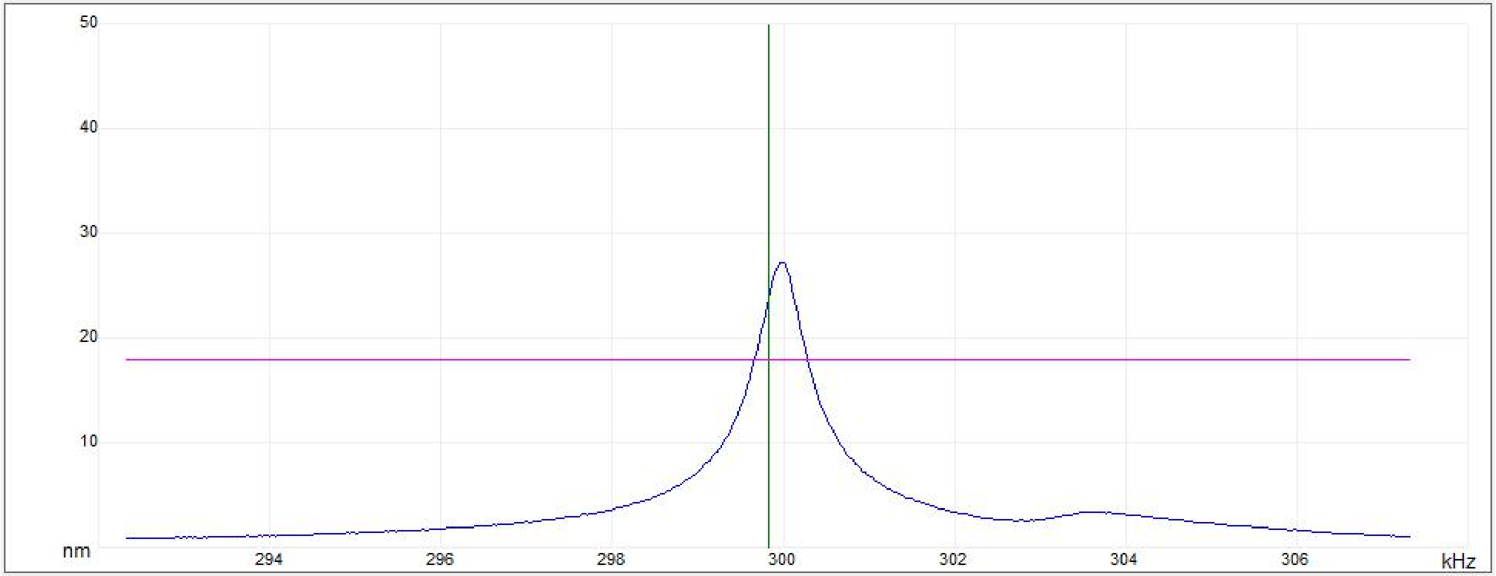
C: Tip symmetry
- 1 – Rotated (Symmetrical)
- 2 – Not Rotated (Asymmetrical)

D: Backside coating
- 0 – None
- 2 – Al

E: Mount or not
- 0 – No
- 3 – Mounted

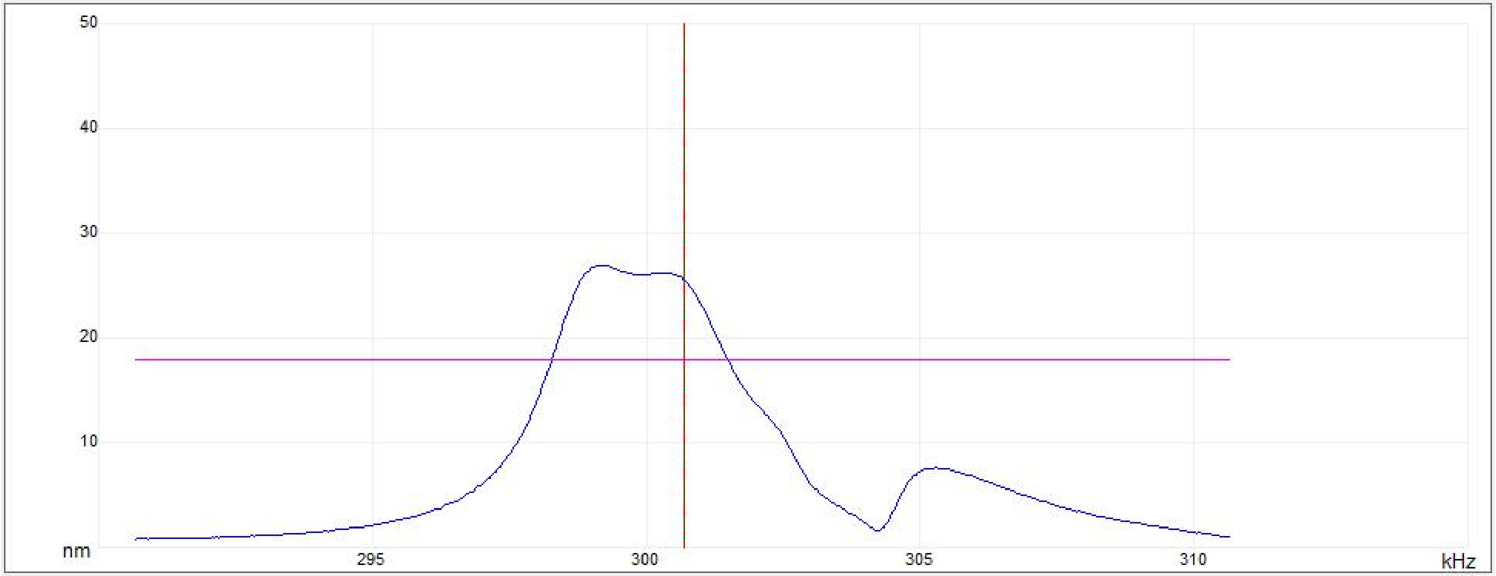
Z: Package
- 10 – 10-pack
- W – Wafer

Tapping Mode Tuning Curve



- Make sure cantilever is seated well in the probe holder
- The tuning curve should have one signal peak
- Do a surface tune or fast thermal tune if needed

Cantilever Tuning Troubleshooting



- Reposition the cantilever in the probe holder
- Clean the probe holder slot
- Make sure the spring clip is holding the probe tightly

ScanAsyst Mode Probes

Spring constant k is usually larger than 0.1 N/m, less than 1 N/m, with backside coating

✓ Common application: ScanAsyst serials, SNL-A/C

ScanAsyst-Air-HR is only used for MM8 ScanAsyst-HR mode

New high resolution ScanAsyst probe: ScanAsyst-Air-HPI

Name	Mount	Description	Pack Size
SCANASYST-AIR	Unmounted	Sharpened, 1 Cantilever, 0.4N/m, Al Reflective Coating	10
SCANASYST-AIR-HR	Unmounted	Fast Scanning, Sharpened, 1 Cantilever, 0.4N/m, Al Ref. Coating	10
SCANASYST-FLUID	Unmounted	1 Cantilever, 0.7N/m, Au Reflective Coating	10
SCANASYST-FLUID+	Unmounted	Sharpened, 1 Cantilever, 0.7N/m, Au Reflective Coating	10

Fluid Imaging Probes

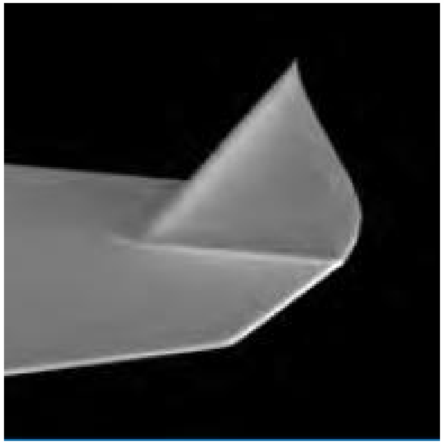
Spring constant k is usually less than 5N/m.

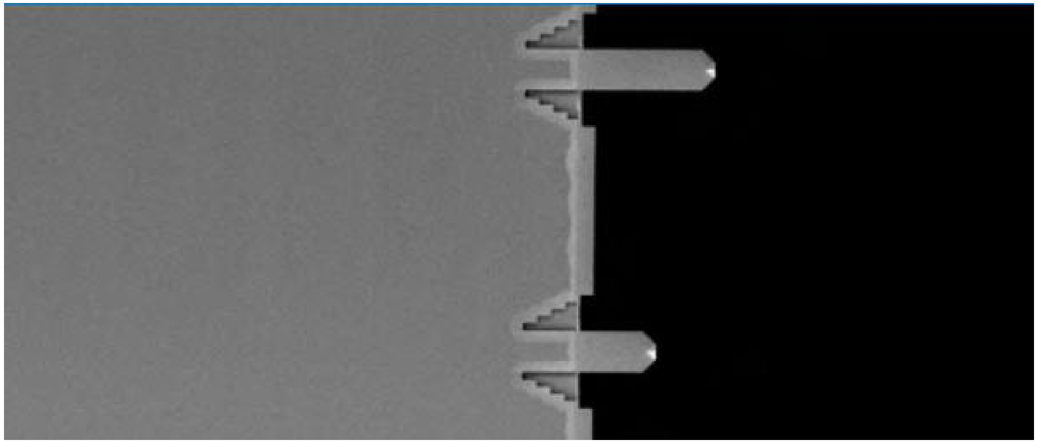
✓ High resolution: SNL serials, MSNL serials(Silicon tip, Nitride cantilever)
✓ Common application: DNP serials, DNP-S serials, MLCT serials, NPG serials (Nitride tip, Nitride cantilever)

SNL-(10/W), DNP(/-10), DNP-S(/10), NPG(/-10)
4 levers 0.06-0.35N/m; Au Reflex Coating

MSNL-(10/W), MLCT (suitable for bio samples)
6 levers, 0.01-0.50N/m, Au Reflex Coating

Biolever





Name	Mount	Description	Pack Size
OBL-10	Unmounted	Au Coated tips; 2 Cantilevers, 0.006-0.03N/m, Au Reflective Coating	10

OBL cantilevers have bend up to +/- 3 deg, which makes them unsuitable for Bruker's Dimension AFM line. **Therefore, these probes are not intended for use on Dimension AFMs.**

The "B" cantilever on the Biolever is one of the softest cantilevers commercially available today.

Nitride Probes: OTR4

Name	Mount	Description	Pack Size
OTR4-10	Unmounted	Sharpened, 2 Triangular Cantilevers 0.02 & 0.08N/m, Au Reflective Coating	10
OTR4-W	Unmounted	Sharpened, 2 Triangular Cantilevers 0.02 & 0.08N/m, Au Reflective Coating	245

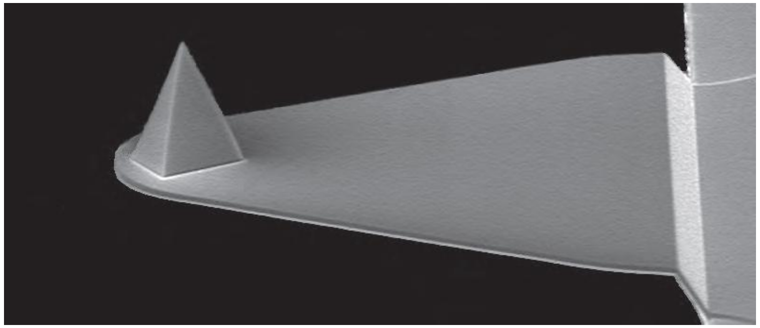
Nitride Probes: OTR8

Name	Mount	Description	Pack Size
OTR8-10	Unmounted	Sharpened, 2 Triangular Cantilevers 0.15 & 0.57N/m, Au Reflective Coating	10
OTR8-W	Unmounted	Sharpened, 2 Triangular Cantilevers 0.15 & 0.57N/m, Au Reflective Coating	490

Fastscan Probes

High frequency and low spring constant probe

- ✓ Fastscan Tapping in air: Fastscan-A
- ✓ Fastscan in fluid: Fastscan-B
- ✓ Fastscan in fluid: Fastscan-C
- ✓ Fastscan in fluid for bio samples: Fastscan-D
- ✓ Fastscan in fluid for fragile samples:
- ✓ USCEBD300KHZ
- ✓ Fastscan in fluid for force curve: AC40



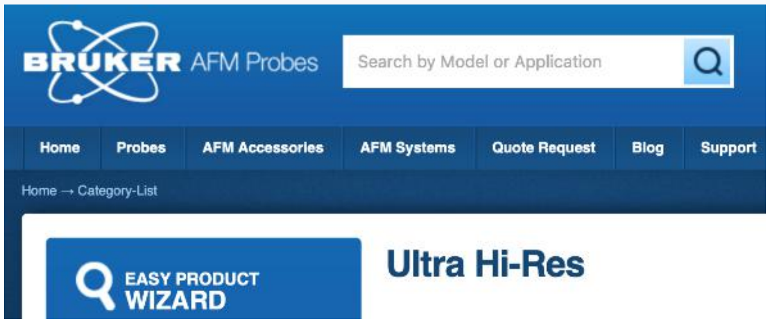
AC40	Unmounted	FastScan	Fast Scanning Bio Sample in Fluid 0.1 N/m
FASTSCAN-A	Unmounted	FastScan	FastScan Probes, 1,400kHz, 17N/m, Al Reflex Coating
FASTSCAN-B	Unmounted	FastScan	FastScan Probes, 400kHz, 4N/m, Au Reflex Coating
FASTSCAN-C	Unmounted	FastScan	FastScan Probes, 250kHz, 1.5N/m, Al Reflex Coating
FASTSCAN-D	Unmounted	FastScan Bio	FastScan-D Bio Probes, 10-pack. 110 kHz (fluid), 250 kHz (air), 0.25 N/m.
USCEBD300KHZ	Unmounted	FastScan	Fast fluid probe, 5-pack. 0.3 N/M, 0.3 MHz, Gold Reflective Coating.

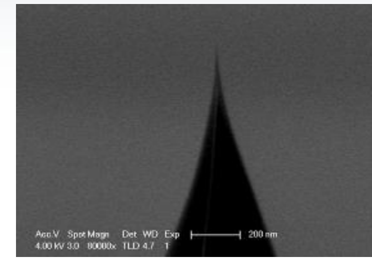
Bruker Super Sharp Probes

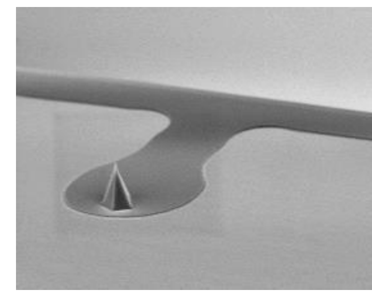
- Dimension Icon system in air, 2kHz PFT
  - ScanAsyst-Air-HPI-SS
  - PeakForce-HiRes-SSB
- Dimension Icon system in liquid, 2kHz PFT
  - PeakForce-HiRes-F-B
- Dimension FastScan in air, 8kHz PFT
  - PeakForce-HiRes-SSB (setpoint need to be around 100pN).
  - PeakForce-HiRes-F-A
- Dimension FastScan in liquid, 8kHz PFT
  - FastScan-D-SS

Link to Website

Bruker Super Sharp Probes







Name	Res. Freq. (kHz)	Spring. Const. (N/m)	Cantilever Length (um)	Tip Radius (nm)
FASTSCAN-D-SS	110	0.25	16	1
PEAKFORCE-HIRS-F-A	165	0.35	36	1
PEAKFORCE-HIRS-F-B	100	0.12	36	1
PEAKFORCE-HIRS-SSB	100	0.12	36	1
SCANASYST-FLUID+	150	0.7	70	2
SNL-10	18-65	0.06-0.35	120/205	2

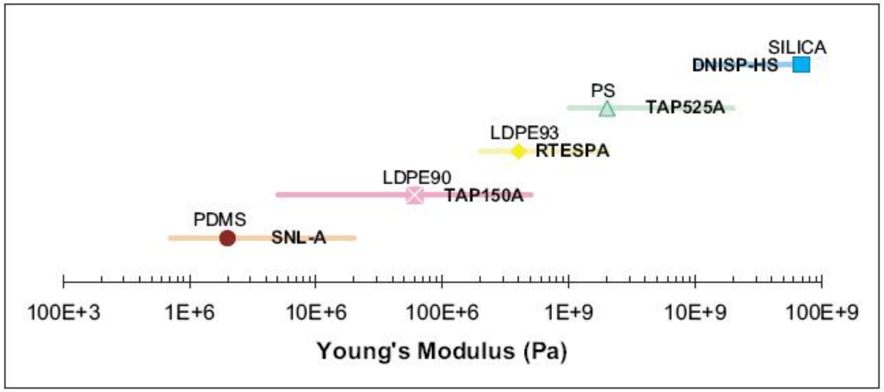
Force Measurement Probes

- Backside coating is preferred for PeakForce tapping mode.
- While the final DMT Modulus value of the unknown sample is not known, typically the range it falls into will be. It is important to choose a probe that produces sufficient sample deformation while still retaining high force sensitivity. Here are Bruker's recommendations:

Table 2.3a Recommended Probes

Sample Modulus (E)	Probe	Nominal Spring Constant (k)
0.7 MPa < E < 20 MPa	SNL-A	0.5 N/m
5 MPa < E < 500 MPa	Tap150A	5 N/m
200 MPa < E < 2000 MPa	RTESPA	40 N/m
1 GPa < E < 20 GPa	Tap525A	200 N/m
10 GPa < E < 100 GPa	DNISP-HS	350 N/m

Figure 4.2a Modulus ranges covered by various probes. The modulus of the reference sample for each range is indicated as well



TAP150A – RTESPA-150, RTESPA – RTESPA-300, TAP525A – RTESPA-525

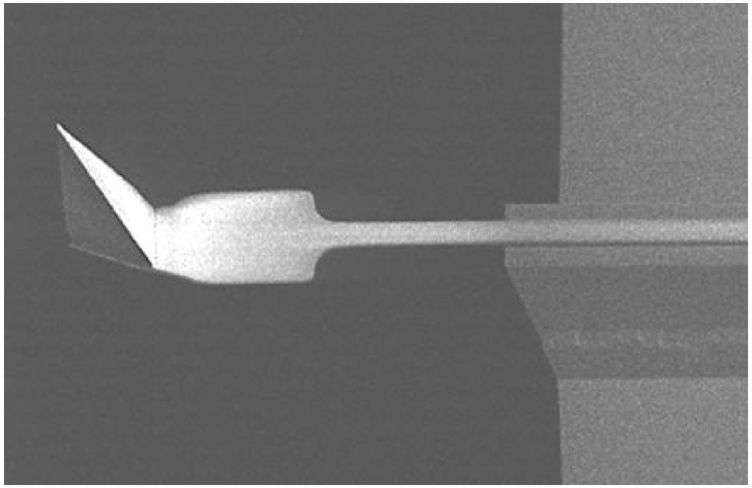
New QNM Probes

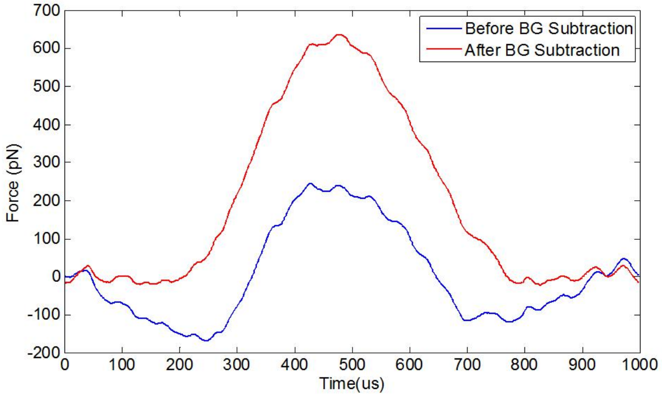
- 4 new QNM probes
  - SAA-HPI-30 (1MPa – 100MPa)
  - RTESPA-150-30 (10MPa – 1GPa)
  - RTESPA-300-30 (100MPa – 10GPa)
  - RTESPA-525-30 (>1GPa)

Pre-calibrated spring constant
Controlled tip radius: **33nm**
Calibration data in QR code

PFQNM-LC Probe

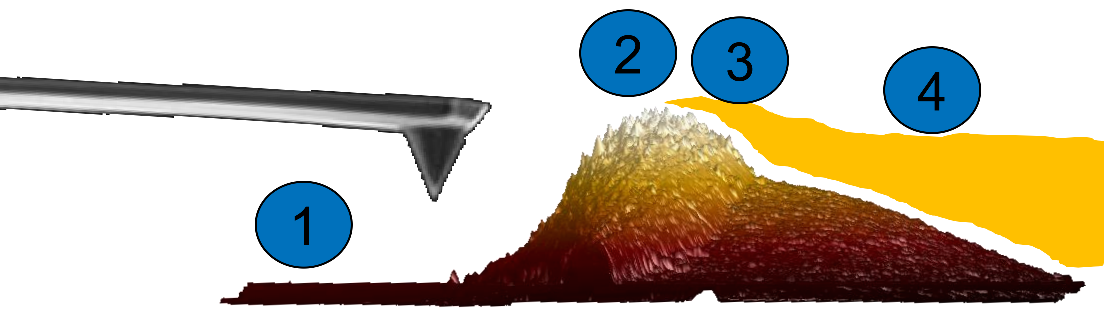
- Problem with large background on live cell imaging.
  - 1kHz drive frequency instead of 250Hz, background increase by 1 order (around 2nN with live cell probe).
  - Desired force on live cell <300pN.
  - Live cell is tall, background change over cell.
- Cell imaging probe, optimized geometry to reduce background, tip height 17um.
- Petri Dish drum effect was removed with Vacuum insert
- Software based background subtraction algorithm

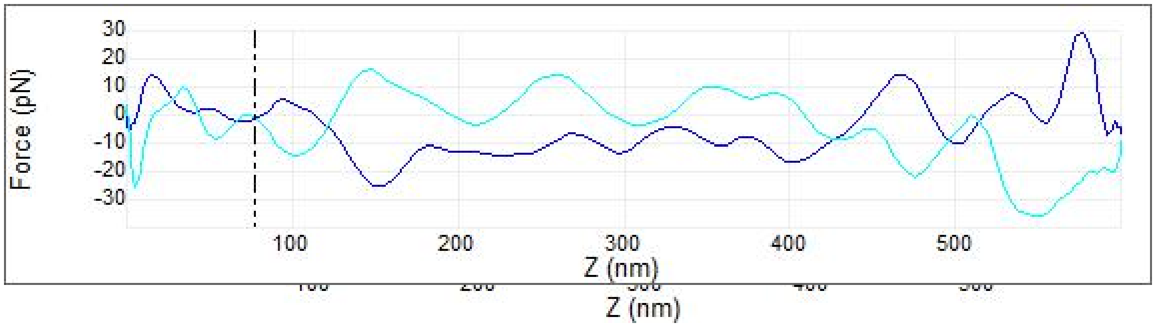


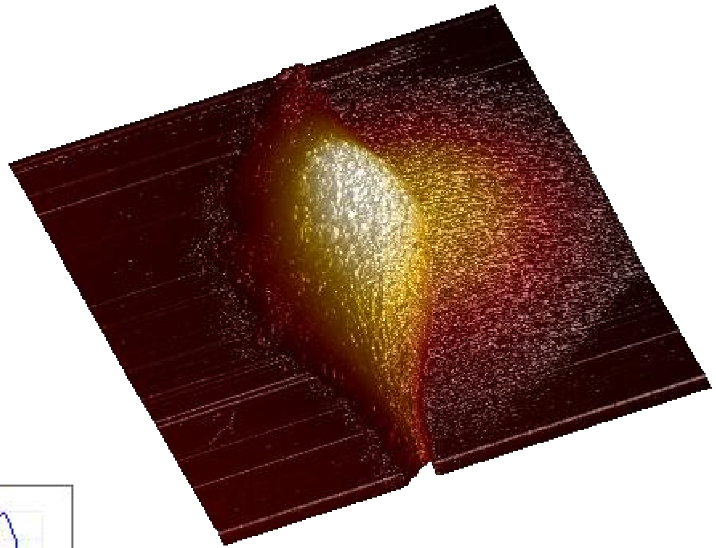


Squeeze Layer Changes Background

Squeeze layer







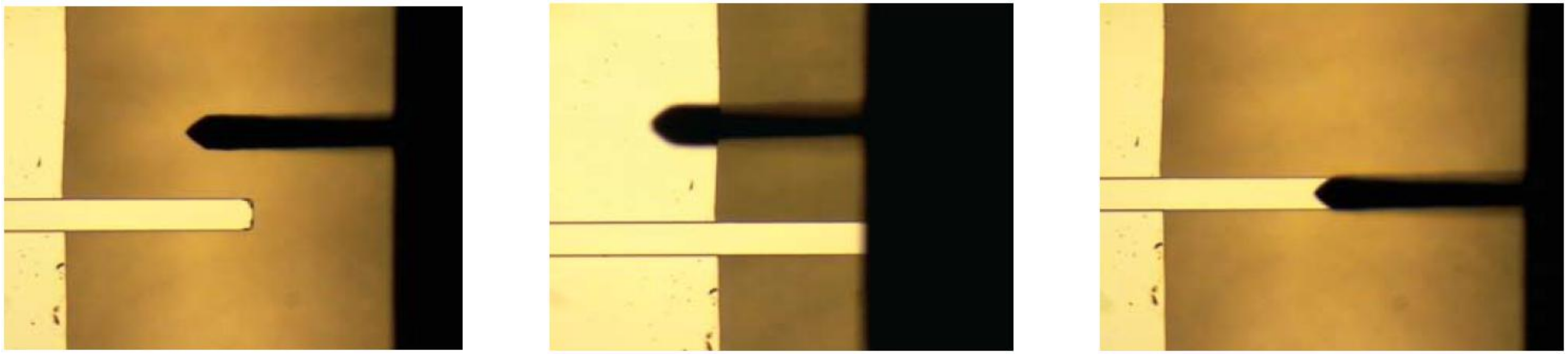
Special Microlever for Modification

Suitable for tip modification

Name	Mount	Description	Pack Size
MLCT-O10	Unmounted	Tipless, 6 Cantilevers, 0.01-0.6N/m, Au Reflective Coating	10
MLCT-OW	Unmounted	Tipless, 6 Cantilevers, 0.01-0.6N/m, Au Reflective Coating	375
MLCT-UC	Unmounted	6 Cantilevers, 0.01-0.6N/m, No Coating	10
MLCT-UCMT-A	Innova®	1 Cantilever, 0.07N/m, No Coating, Pre-Mounted For Innova AFM	10
MLCT-UCMT-BF	Innova	5 Cantilevers, 0.01-0.6N/m, No Coating, Pre-Mounted For Innova AFM	10
MSCT-UC	Unmounted	Sharpened, 6 Cantilevers, 0.01-0.6N/m, No Coating	10
MSCT-UCMT-A	Innova	Sharpened, 1 Cantilever, 0.07N/m, No Coating	10
MSCT-UCMT-BF	Innova	Sharpened, 5 Cantilevers, 0.01-0.6N/m, No Coating	10

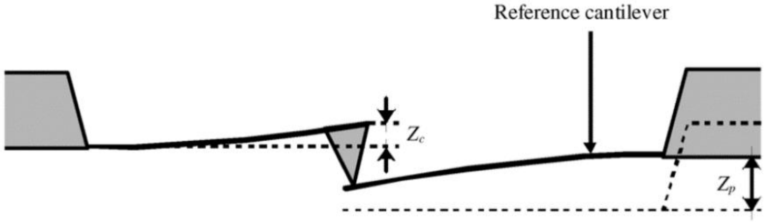
Static Deflection Method for Spring Constant Calibration

➢ Using a calibrated reference cantilever



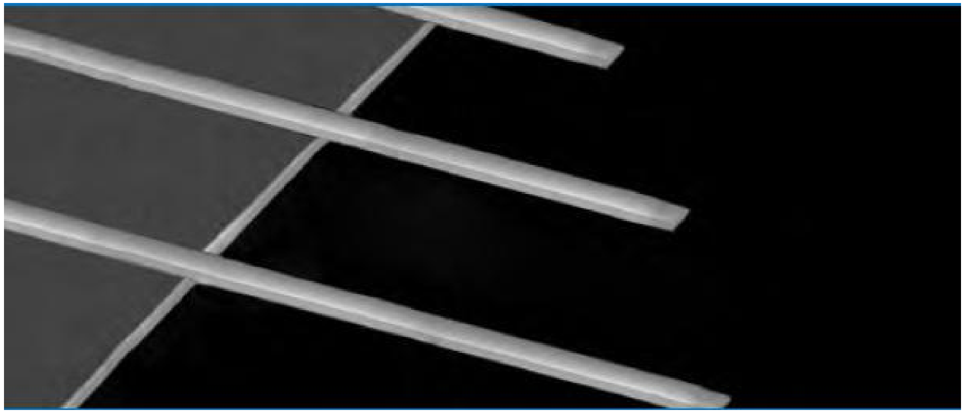
The cantilever to be calibrated is used to measure a force curve on the end of a second cantilever that is calibrated. The slope of the contact portion of the force curve is compared to that measured on a hard surface (i.e. the deflection sensitivity in nm/V) and the spring constant calculated from:

$$k = k_{ref}\left(\frac{S_{ref}}{S_{hard}} - 1\right)$$



where k_{ref} is the spring constant of the reference cantilever, S_{ref} is the deflection sensitivity measured on the reference cantilever, and S_{hard} is the deflection sensitivity measured on a hard surface.

Calibration Probes



Name	Mount	Description	Pack Size
CLFC-NOBO	Unmounted	Calibration Probes, Three Cantilevers with Different k	5
CLFC-NOMB	Innova®	Calibration Probes, Three Cantilevers with Different k	5

Cantilever Type	Frequency (kHz)	k (N/m)	Width (µm)	Thickness (µm)	Length (µm)
A (Rectangular)	293	10.4	29	2	97
B (Rectangular)	71	1.3	29	2	197
C (Rectangular)	18	0.16	29	2	397

Bruker Value Line Probe

- ✓ Contact mode in air: CONTV-(/A/W/AW)
- ✓ Soft Tapping/Phase imaging/FMM: FMV-(/A/W/AW)
- ✓ Tapping mode in air: NCHV-(/A/W/AW)
- ✓ Tapping mode in air (Long level): NCLV-(/A/W/AW)
- ✓ Electric measurement: CONTV-PT, FMV-PT
- ✓ Magnetic measurement: MFMV

Commonly Used Probes Overview

- **ScanAsyst Mode:** ScanAsyst-Air, ScanAsyst-Fluid, ScanAsyst-Fluid+, SNL
- **Contact Mode:** DNP, SNL, MLCT
- **Tapping Mode:** TESPA, RTESPA, OTESPA
- **Phase Imaging:** FESPA, OLTESPA
- **EFM/KPFM:** SCM-PIT, MESP
- **MFM:** MESP, MESP-RC
- **PFM:** DDESP, MESP-RC
- **cAFM/TUNA/SCM:** SCM-PIC, SCM-PIT, MESP
- **Nano-Indentation:** DNISP

Probe Selection Guide — Life Science

Sample Type		Imaging Environment: Liquid	Imaging Environment: Air	Probe Family / Model		Nominal Specifications: Force Constant (N/m)	Resonant Frequency (kHz)	Radius of Curvature (nm)	Coatings: Backside	Coatings: Tip Side	Probe Attributes	AFM Mode: Peak Force/ Scan Asyst	Tapping	Contact	Force Curves	Electrical	Magnetic
Life Sciences	Biomolecules (nucleic acids, proteins, lipids, carbohydrates, etc.)	-	✓	Silicon	TESPA	42	320	8	Al	None	Highest Resolution, Asymmetric Tip		✓	-	-	-	-
		-	✓		RTESPA	40	300	8	Al	None	Highest Resolution, Symmetric Tip		✓	-	-	-	-
		-	✓		NCHV-A	42	320	10	Al	None	High Resolution, Asymmetric Tip		✓	-	-	-	-
		✓	✓	Silicon Nitride	DNP-S	0.06-0.58	18-57	10	Au	None	High Resolution, Low Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
		✓	✓		MSCT	0.01-0.5	7-120	10	Au	None	High Resolution, Lowest Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
		✓	✓		SNL	0.06-0.58	18-57	2	Au	None	Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
		✓	✓		MSNL	0.01-0.5	7-120	2	Au	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
		✓	✓		ScanAsyst-Air	0.2-0.8	45-95	2	Al	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
		✓	-		ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None	High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
		✓	-		ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
	Cells	✓	-	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None	Low Force, Symmetric Tip		✓	✓	✓	-	-
		✓	-		MLCT	0.01-0.5	7-120	20	Au	None	Lowest Force, Symmetric Tip		✓	✓	✓	-	-
	Tissues	-	✓	Silicon	TESPA	42	320	8	Al	None	Highest Resolution, Asymmetric Tip		✓	-	-	-	-
		-	✓		RTESPA	40	300	8	Al	None	Highest Resolution, Symmetric Tip		✓	-	-	-	-
		-	✓		NCHV-A	42	320	10	Al	None	High Resolution, Asymmetric Tip		✓	-	-	-	-
		✓	-	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None	Low Force, Symmetric Tip		✓	✓	✓	-	-
		✓	-		DNP-S	0.06-0.58	18-57	10	Au	None	High Resolution, Low Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
		✓	-		MLCT	0.01-0.5	7-120	20	Au	None	Lowest Force, Symmetric Tip		✓	✓	✓	-	-
		✓	-		MSCT	0.01-0.5	7-120	10	Au	None	High Resolution, Lowest Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
		✓	-		SNL	0.06-0.58	18-57	2	Au	None	Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
		✓	-		MSNL	0.01-0.5	7-120	2	Au	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
		✓	✓		ScanAsyst-Air	0.2-0.8	45-95	2	Al	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
		✓	-		ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None	High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
		✓	-		ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-

Probe Selection Guide — Material

Materials	Sample Type	Imaging Environment: Liquid	Imaging Environment: Air	Probe Family	Model	Force Constant (N/m)	Resonant Frequency (kHz)	Radius of Curvature (nm)	Coatings: Backside	Coatings: Tip Side	Probe Attributes	Peak Force/ Scan Asyst	Tapping	Contact	Force Curves	Electrical	Magnetic
Materials	Polymers / Soft Samples	-	✓	Silicon	FESP	2.8	75	<10	None	None	High Resolution, Lower Force, Asymmetric Tip		✓	-	✓	-	-
		-	✓		TESPA	42	320	8	Al	None	Highest Resolution, Asymmetric Tip		✓	-	✓	-	-
		-	✓		LTESP	48	190	<10	None	None	High Resolution, Long-Lever, Asymmetric Tip		✓	-	✓	-	-
		-	✓		NCHV-A	42	320	10	Al	None	High Resolution, Asymmetric Tip		✓	-	✓	-	-
		✓	✓	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None	Low Force, Symmetric Tip		✓	✓	✓	-	-
		✓	✓		SNL	0.06-0.58	18-57	2	Au	None	Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
		-	✓		MLCT	0.01-0.5	7-120	20	Au	None	Lowest Force, Symmetric Tip		-	✓	✓	-	-
		✓	✓		ScanAsyst-Air	0.2-0.8	45-95	2	Al	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
		✓			ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None	High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
		✓			ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
	Hard Samples	-	✓	Silicon	TESPA	42	320	8	Al	None	Highest Resolution, Asymmetric Tip		✓	-	-	-	-
		-	✓		NCHV-A	42	320	10	Al	None	High Resolution, Asymmetric Tip		✓	-	-	-	-
		-	✓		RTESPA	40	300	8	Al	None	Highest Resolution, Symmetric Tip		✓	-	-	-	-
		-	✓	Modified Silicon	MESP-RC	2.8	75	25	Co/Cr	Co/Cr	High Performance, Magnetic Characterization, Asymmetric Tip		✓	-	-	✓	✓
		-	✓		SCM-PIC	0.2	13	20	Pt-Ir	Pt-Ir	High Performance, Electrical Characterization, Asymmetric Tip		-	✓	-	✓	-
		-	✓		SCM-PIT	2.8	75	20	Pt-Ir	Pt-Ir	High Performance, Electrical Characterization, Asymmetric Tip		✓	-	-	✓	-
		-	✓		DDESP	42	320	35	Doped Diamond	Al	Conductive, with Increased Wear Resistance		-	✓	-	✓	-
		✓	✓	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None	Low Force, Symmetric Tip		✓	✓	-	-	-
		✓	✓		SNL	0.06-0.58	18-57	2	Au	None	Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	-	-	-
		✓	✓		ScanAsyst-Air	0.2-0.8	45-95	2	Al	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
		✓			ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None	High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
		✓			ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None	Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-

Probe Selection Guide — Mouse Pad

常用探针选型指南

材料样品

		大气环境	液下环境
智能成像	高分辨	ScanAsyst-Air, SNL-A/C	ScanAsyst-Fluid+, SNL-A/C
	一般成像	DNP-A/C	ScanAsyst-Fluid, DNP-A/C
轻敲模式	较软样品/相位成像	OLTESPA, RTESPA-150	SNL, DNP
	一般样品	OTESPA, RTESPA-300	SNL, DNP
	快速扫描	Fastscan-A	Fastscan-B, Fastscan-C
接触模式	一般成像	SNL, DNP, MLCT	SNL, DNP, MLCT
	摩擦力显微镜	ORC-8, SNL, DNP	ORC-8, SNL, DNP

电磁学测量

静电力显微镜	MESP-RC, MESP, SCM-PIT
磁力显微镜	MESP-RC, MESP
表面电势测量	PFQNE-AL, MESP-RC, MESP, OSCM-PT, SCM-PIT
导电原子力/隧穿原子力	MESP-RC, MESP, SCM-PtSi, OSCM-PT, SCM-PIC, SCM-PIT
峰值力隧穿原子力显微镜	PFTUNA, MESP-RC, MESP, SCM-PtSi, SCM-PIT
扫描电容显微镜	OSCM-PT, SCM-PtSi, SCM-PIT
扫描扩散电阻显微镜	SSRM-DIA, DDESP, DDESP-FM, OSCM-PT, SCM-PtSi, SCM-PIT
压电力响应显微镜	DDESP, DDESP-FM, MESP-RC, MESP, OSCM-PT, SCM-PtSi, SCM-PIT

生物样品

生物小分子	一般成像	MLCT, DNP, DNP-S
	高分辨	SNL, FastScan-D, AC40
细胞	一般成像	MLCT, DNP
	力学测量	MLCT, DNP, ScanAsyst-Fluid, PFQNM-LC
探针修饰	修饰小球	NP-O
	修饰分子	NP-G

力学测量

杨氏模量 (E)	探针类型	弹性常数 (k)
1 MPa < E < 20 MPa	ScanAsyst-Air *, SNL-A	0.5 N/m
5 MPa < E < 500 MPa	RTESPA-150	5 N/m
200 MPa < E < 2000 MPa	RTESPA-300	40 N/m
1 GPa < E < 20 GPa	RTESPA-525	200 N/m
10 GPa < E < 100 GPa	DNISP-HS	350 N/m

* 镀层为Al的探针一般不用于液下环境。

用于高分辨成像的超尖探针

Dimension Icon	大气环境	ScanAsyst-Air-HPI-SS PeakForce-HiRes-SSB
	液下环境	PeakForce-HiRes-F-B
Dimension FastScan	大气环境	PeakForce-HiRes-SSB * PeakForce-HiRes-F-A
	液下环境	FastScan-D-SS

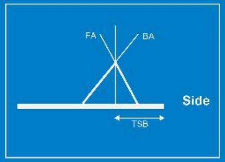
* Setpoint need to be around 100pN

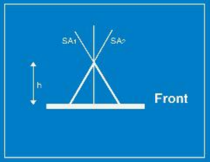
Resonance Frequency (without tip mass):

$$f_o = 0.162\sqrt{\frac{E}{\rho}}\cdot\frac{t}{L^2} \approx \frac{1}{2\pi}\sqrt{\frac{E}{\rho}}\cdot\frac{t}{L^2} \qquad f_0 = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Spring Constant：

$$k = \frac{E}{4}\frac{w\cdot t^3}{L^3}$$





$$\text{Half angle} = \tan^{-1}\left(\sqrt{\tan\alpha * \tan\beta}\right)$$

$$\alpha = \frac{FA+BA}{2} \qquad \beta = \frac{SA_1+SA_2}{2}$$

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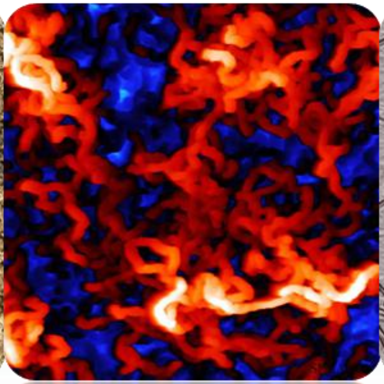
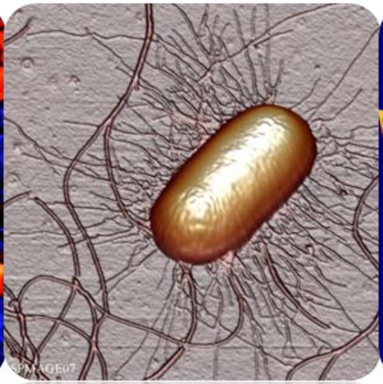
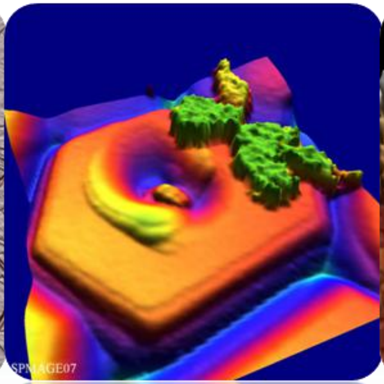
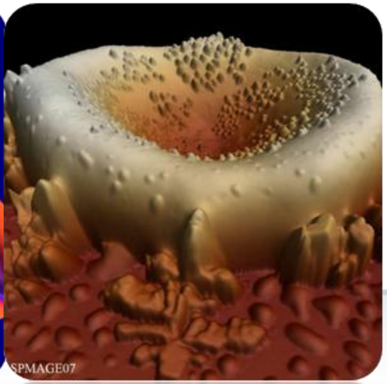
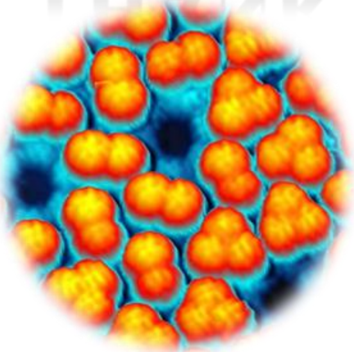
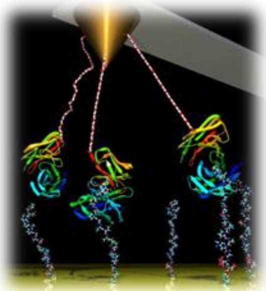
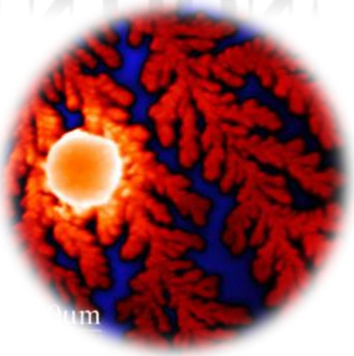







THANK YOU FOR YOUR ATTENTION!

Small Tip Big Science